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**U.S. DEPARTMENT OF ENERGY**
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# REFLECTION PLANE TESTS OF A WIND TURBINE BLADE TIP SECTION WITH AILERONS

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## SUMMARY

Tests were conducted in the NASA Langley 30- by 60-Foot Wind Tunnel on a full scale 7.31 m (24 ft) long tip section of a wind turbine rotor blade. The blade tip section was built with ailerons on the trailing edge. The ailerons, which spanned a length of 6.1 m (20 ft), were designed so that two types could be evaluated: the plain and the balanced. The ailerons were hinged on the suction surface at the 0.62 X chord station behind the leading edge. The purpose of the tests was to measure the aerodynamic characteristics of the blade section for: an angle-of-attack range from 0° to 90°, aileron deflections from 0° to -90°, and Reynolds Numbers of 0.79 and $1.5 \times 10^6$. These data were then used to determine which aileron configuration had the most desirable rotor control and aerodynamic braking characteristics. Tests were also run to determine the effects of vortex generators, leading edge roughness, and the gaps between the aileron sections on the lift, drag, and chordwise force coefficients of the blade tip section

The important result to emerge from the wind tunnel test was that the plain aileron produced better rotor control and aerodynamic braking characteristics than did the balanced ailerons. The vortex generators produced a sizable increase (up to 56 percent) in the chordwise force coefficient which should significantly increase rotor performance. The aileron gaps degraded the lift and increased the drag. The leading edge roughness, on the other hand, produced largely negligible effects on most of the aerodynamic characteristics with a minor effect on the drag coefficient at low angles of attack when the ailerons were undeflected.

## INTRODUCTION

The NASA Wind Energy Project Office, under the sponsorship of the U.S. Department of Energy has been evaluating various aileron concepts as a method for (1) controlling the output power of large (over 30 m in diam) propeller type wind turbines, (2) protecting the rotors from overspeeding, and (3) reducing the rotational speed to a low value (preferably to a complete stop) in the event of a loss-of-load emergency. NASA Lewis has an experimental wind turbine, the Mod-0 shown in figure 1, which is used to conduct field tests on innovative concepts such as aileron controlled rotors.

In mid 1983, a decision was made to build three 7.31 m (24 ft) long blade sections which would have ailerons over 6.1 m (20 ft) of the span. Two of the three sections were mounted on the ends of a two-bladed rotor which measured

24.4 m (80 ft) to form the outboard sections of a rotor measuring 39 m (128 ft) from tip to tip. The rotor was field tested to determine the control and shutdown characteristics of both aileron configurations. The third outboard blade section was built for simultaneous testing in the NASA Langley 30- by 60-Foot Wind Tunnel under steady uniform wind conditions. The purpose of wind tunnel tests was to measure the aerodynamic characteristics of the blade section under steady uniform wind conditions. Among the aerodynamic properties of interest were the lift, drag, and moment coefficients of the blade section, the aileron hinge moment coefficient, and chordwise surface pressure distributions at one spanwise station. These properties were measured at angles-of-attack from 0° to 90° for: (1) aileron deflections from 0° to -90°, (2) tripped and smooth (as built) leading edge conditions, and (3) with vortex generators on suction surface.

The purposes of this report are to document the results of the tests and to present some of the key results and conclusions.

## SYMBOLS

$A_a$ total projected area of the ailerons

$A_B$ projected planform area of the blade tip section

C proportionality constant relating the force on the aileron push rod to the aileron system hinge moment

$C_C$ chordwise force coefficient

$C_D$ drag coefficient

$C_L$ lift coefficient

$C_M$ pitching moment coefficient

$C_N$ chord normal force coefficient

$C_{am}$ aileron hinge moment

D total drag force on the blade tip section

L total lift force on the blade tip section

M total pitching moment on the blade tip section

$M_{am}$ total hinge moment on the aileron system

b span length of the blade tip section

$b_a$ span length of the aileron section

$c_B$ mean chord length of the blade tip section

$c_{root}$ chord length at the root end of the blade tip section

$c_{tip}$ chord length at the tip end of the blade tip section

$c_a$ mean chord of the aileron

q dynamic pressure of the free stream

V freestream windspeed

y spanwise location of the mean chord of the blade tip section

$\alpha$ angle of attack (angle between the wind tunnel jet stream and the chordline at the root end of the blade tip section)

$\lambda$ taper ratio of the blade tip section

$\rho$ air density

## APPARATUS AND PROCEDURES

### Blade Tip Section

In figure 2 is sketched the configuration of the blade section. In figure 3 is a view of the blade section when it was installed in the NASA Langley 30- by 60-Foot Wind Tunnel. The blade section was made with a NACA 23024 airfoil at the root end, a NACA 64-621 airfoil 1.22 m (4 ft) away from the root end, and a NACA 64-615 airfoil at the tip. The planform taper was linear from root to tip whereas the thickness varied linearly only over the outer 6.1 m which utilized only the NACA 64-XXX airfoil sections. The tip was rounded approximately as sketched. The suction side of tip cap was an extension of the suction surface of the blade, whereas, the pressure side of the tip cap was beveled toward the suction side. The twist distribution, referenced relative to the root end of the blade, is -3° (nosedown) at inboard end of the aileron section and -1° at the blade tip. This twist distribution, which is unorthodox for a wind turbine, was dictated by the requirement that it duplicate the twist distribution designed into the blade tip span of Mod-5A wind turbine. (The Mod-5A was terminated after the design phase.)

The aileron section was 6.1 m (20 ft) in length and consisted of six segments of equal length, (fig. 2). Each segment was rigidly attached to the adjacent segments with 4.8 mm (3/16 in) gap between the ends of the segments. When deflected (by a hydraulic actuator enclosed within the root end of the blade section) all segments moved together as though the aileron segments were a single unit. Segmented hinges were used to attach the ailerons to the main blade structure. The hinge line was located on the suction surface at a location 62 percent of the chord (measured along the chord line and not along the suction surface) behind the leading edge. Along the hinge line there were, as shown in figure 2, gaps between the ends of the hinge segments, and between the upper front edge of the ailerons and the upper back edge of the blade section. These gaps measured approximately 205 by 11 mm (8 1/16 by 7/16 in). Gaps 12 mm (1/2 in) also existed at both ends of the aileron span.

The reason for highlighting the presence of the gaps is because it was suspected before the tests (and subsequently proven by the tests) that the gaps would have a significant effect on the lift and drag coefficient due to the air leakage from the pressure side to the suction side.

As shown in figure 2(b), the ailerons were designed so that two separate configurations could be tested: the plain and the balanced. This was accomplished with the use of removable inserts which were attached to the main blade structure to form the plain aileron and additions that were fastened to the plain aileron to form the balanced aileron. A foam rubber strip was glued as shown to the rear edge of the inserts to form a seal when the plain aileron was in the undeflected position.

The blade section structure was similar that of an aircraft wing, and the three units were fabricated from aluminum. The aileron actuator system was housed inside the blade between the root end of the blade section and the ailerons. No special efforts were made to fabricate the leading edge portion of the blade to be aerodynamically smooth. Standard construction methods and spray painting techniques were employed to form and finish the leading edge. The paint finish was not sanded or buffed to produce a smoother leading edge surface. This surface was judged not to be smooth in the aerodynamic sense, but also the leading edge was not rough enough to be classified as rough.

One goal of large wind turbine designs is low operation and maintenance costs. Because they are expected to operate for long periods of time unattended in all types of atmospheric conditions, the blades will not maintain aerodynamically smooth leading edges, even if they are so initially. For this reason it was decided to do most of the testing with two leading edge trip strips, one on the suction surface and one on the pressure surface. The trip strips were 25 mm (1 in) wide by 0.25 mm (0.010 in) thick duct tape with one straight edge and the other with a sawtooth pattern. The sawtooth edges of both trip strips faced downstream, and were located a 0.075 X chord behind the leading edges along the chordline (not along the airfoil surface) (fig. 2(b)).

## Vortex Generators

Vortex generators (VGs) have been proven to improve the performance of large wind turbines (ref. 1). Field tests have been run on the 91.4 m (300 ft) diameter Mod-2 with and without VGs. The Mod-2 blades are built using a slightly modified form of the NACA 230XX airfoil series. The test results showed that the VGs reduced the rated wind speed by about 2.25 mps (5 mph). (The rated windspeed is the lowest value at which full power is achieved.) On the basis of these results, it was decided to measure the effect the VGs might have on the blade tip section built with NACA 64-6XX airfoil series under non-rotating conditions in a uniform wind. The sizes of the VGs and their installation pattern on the blade section were determined from the Mod-2 experience, and are shown in figure 4.

## Surface Pressure Measuring Cuff and the Angle-of-Attack Probe

The tests of the blade section included: (1) measurement of the surface pressure distributions in the chordwise direction at one spanwise station near midspan at a location 3.75 m (12.3 ft) from the root end, using a pressure sensing cuff, and (2) calibration measurements of an angle-of-attack probe both of which were used on a Mod-0 rotor blade during field tests.

The pressure cuff method of measuring surface pressures was selected because it had been successfully used on aircraft wings in steady flight, and on a rotating Mod-0 wind turbine blade which is usually exposed to unsteady, turbulent winds. In the unsteady, turbulent winds it was anticipated that the surface pressures would also be unsteady. It is well known that unsteady surface pressure distribution can be significantly different than steady ones, especially near stall. Hence, the reasons for testing the pressure cuff in these tests were (1) to acquire reference surface pressure data under steady flow conditions against which unsteady pressures measured in the field can be compared and (2) to check out the operation of the pressure cuff, associated instrumentation and data recording equipment prior to using it in field tests on the Mod-0.

The pressure measuring cuff system, shown schematically in figure 5(a), consisted of a belt of 32 0.125 in O.D. by 0.040 in I.D. plastic tubes. A single static pressure tap 0.040 in diameter was bored into each tube. The bored taps locations were selected so that the chordwise surface pressure distributions could be accurately measured. A 32 channel pressure transducer was used for this measurement system. The pressures were recorded by a system which is shown schematically in figure 5(b). The pressure cuff was attached to the blade section with RTV silastic rubber cement.

The reasons for calibrating the angle-of-attack probe are similar to those for making chordwise pressure measurements. In addition to measuring the instantaneous chordwise surface pressure distributions on a rotor, it is important to also know the angle of attack at the same instant and spanwise location as the pressure cuff. On a rotating wind turbine rotor there is no undisturbed free stream just ahead of the blade such as there is ahead of an aircraft wing. Furthermore, a wind turbine rotor blade frequently operates at and above stall whereas aircraft wings always operate in the attached flow regime below stall. The angle-of-attack probe was designed to be supported on a guyed boom at a location one chord length in front of the leading edge on an extension of the chordline (fig. 6). This is not far enough out to be in the undisturbed free stream, especially at high angle-of-attack at stall and beyond. Hence, the reason for calibrating the angle-of-attack under uniform steady wind conditions in a wind tunnel.

Except for the pressure cuff and the angle-of-attack probe, all auxiliary tubes and wiring were passed through the inside of the blade to under the turntable where the recording equipment was located.

## Wind Tunnel and Test Method

The 30- by 60-Foot Wind Tunnel of NASA Langley Research Center was chosen as the facility in which to conduct the tests. The blade section was mounted vertically on a turntable, the surface of which was flush with that of a large horizontal platform, located in the open test section of the tunnel (fig. 7). This turntable was remotely adjustable to any angle setting up to $\pm 360°$. The aerodynamic and gravity forces and moments imposed on the blade section were transmitted by way of the turntable to a force balance measuring system. The chordline at the root end of the blade was aligned with the turntable reference diameter which had a 0° marking at one end and 180° mark at the other end. Hence, the angle-of-attack of the blade tip section was measured relative to the turntable reference diameter line and the angle-of-attack settings reported herein (after being corrected for a slight tunnel flow angularity) are relative to the root end chordline.

A portable hydraulic supply system, located in a space under the test platform, was used to supply the power needed to deflect the ailerons and hold them in any desired position. Thus, to run a test at any predetermined angle-of-attack and aileron deflection angle, these two angles were set remotely with the wind tunnel not running. After the two angles were set and locked, the wind tunnel was brought up to speed and allowed to settle out to a steady windspeed. Then all the relevant data was recorded.

## TESTS

### Blade Tip Section Configuration

Various blade tip-section configurations were tested. These configurations are listed in table I, each of which was tested for the reason given in the last column of the table.

The first tests were those with the pressure cuff and angle-of-attack probe installed on the blade tip-section. When the surface pressure and angle-of-attack probe calibration tests were completed, only the probe was removed because it was believed that the pressure cuff would not measurably affect the aerodynamic characteristics of the blade tip-section. One primary reason for not removing the cuff was to avoid the need of having to reinstall it on the blade for possible field testing in the future. However, when the time came to change from the plain ailerons to the balanced ailerons, it was found that the changeover could not be made without removing the cuff. Hence, the tests of the balanced aileron were run without the pressure cuff on the blade.

### Test Measurements

This test program was divided for convenience into four broad types:

(1) Aerodynamic force coefficient measurements.
(2) Chordwise surface pressure measurements.
(3) Angle-of-attack probe calibration tests.
(4) Flow visualization experiments.

(Tests 2 and 3 were run concurrently. Each of these tests are outlined in greater detail later in the report.)

Aerodynamic force and moment coefficient measurements. - The net aerodynamic forces and pitching moment imposed on the tip section were transmitted to and measured at the turntable by existing instrumentation. The desired coefficients to be determined from the force and pitching moment measurements were the

$$\text{Lift Coefficient, } C_L = \frac{L}{qA_B}$$

Drag Coefficient, $C_D = \frac{D}{qA_B}$

Pitching moment at the 1/4 chord, $C_M = \frac{M}{qA_B c_B}$

Chordnormal force, $C_N = C_L \cos \alpha + C_D \sin \alpha$
Chordwise force, $C_C = C_L \sin \alpha - C_D \cos \alpha$

where

$A_B$ = planform area of the blade tip section
$c_B$ = mean chord of the tip section where

$$c_B = \frac{2}{3} \times c_{root} \times \frac{(1 + \lambda + \lambda^2)}{(1 + \lambda)}$$

$\lambda$ = Taper ratio

$$= \frac{c_{tip}}{c_{root}}$$

The spanwise location, y, of $C_M$ is given by

$$y = \frac{b}{2} \times \frac{1 + 2\lambda}{3(1 + \lambda)}$$

b = tip section length
$q = \frac{\rho V^2}{2}$, the dynamic pressure of the freestream
$\alpha$ = angle of attack measured between root end chordline and the freestream
L = total lift force on the tip section
D = total drag force on the tip section
M = total pitching moment on the tip section
$\rho$ = air density

Another important coefficient measured was the aileron hinge moment. This coefficient is defined as $C_{am} = \frac{M_{am}}{qA_a c_a}$

where

$M_{am}$ = the total aileron hinge moment
$c_a$ = the aileron chord calculated using the equation for $c_B$
$A_a$ = aileron projected area

The $M_{am}$ was extracted from the strain gage on the aileron actuator as outlined in the Appendix A.

Chordwise surface pressure measurements and angle-of-attack probe calibration. - These two tests were conducted concurrently. The test matrix for these tests is shown in figure B1 in Appendix B. However, none of the test results are presented in this document.

Flow visualization. - The purpose of these experiments was to determine the flow pattern in the neighborhood of the upper surface of the tip section when the aileron deflections are large, of the order of -30° to -90°. The visualization was accomplished with tufts which were attached to the upper surface of the blade. The tufts were attached in rows that run in the chordwise direction from the leading edge to the trailing edge in the region close to the inboard end of the aileron. The tuft patterns were recorded on video tape using the existing TV cameras and recording equipment. Recordings were made for a selected number of conditions. However, these results are not reported in this document.

## Matrices of Test Conditions and Parameters

The matrices of angles-of-attack, aileron deflections and test conditions for which the various coefficients were determined are shown in Appendix B and are summarized in table II.

Because the Mod-0 rotor blades operate at Reynolds Numbers between one and two million, depending on the rotational speed, wind speed, and the local chord length, it was the objective of this test to acquire data within this range of Reynolds Number. At the time of the tests, however, the Langley 30 by 60 Foot Wind Tunnel could operate continuously at windspeeds only up to ~61 mph. Hence, the tests at the matrix points of Appendix B were run at 61 mph, which corresponds to a Reynolds Number of $1.5 \times 10^6$ based on the mean chord of the tip section. To determine the effect of Reynolds Number, data were collected for selected matrix points of Appendix B at about 33 mph ($Re = 0.79 \times 10^6$).

## Data Collection, Processing, and Presentation

The tip section force and moment data were measured with the existing instrumentation on the turntable and data acquisition system. These data were collected under steady state conditions for each of the test matrix points as specified in the Appendix B. The data were processed to yield the force and pitching moment coefficients defined earlier in this document. Corrections were made to the raw data for tunnel blockage effects and for a slight angularity of the tunnel flow. All the results are presented in tabular form in tables III to XI.

# RESULTS AND DISCUSSION

In this report are documented all the aerodynamic force and moment coefficients derived from the wind tunnel tests. Only the key results, such as the effects of trip-strips, vortex generators, aileron deflections and the aileron gaps on the lift, drag, and chordwise force coefficients will be discussed. What are not discussed are the results pertaining to the aileron hinge moment coefficients, and the blade tip moment coefficients, and the chordnormal force coefficients.

Also not included in this document are: (1) the measured chordwise surface pressure distribution, (2) the angle-of-attack probe calibration data, and (3) the results of the video visualization recordings. These three items are intended to be the subject of other reports.

All the aerodynamic force and moment coefficients are contained in tables III to XI. For convenience the test conditions, test variables, and parameters are summarized in table II.

## Aerodynamic Braking and Control Characteristics

The aerodynamic characteristics of primary interest are the ones concerned with the ability of the ailerons to control the power of a wind turbine and to protect the rotor from overspeeding under emergency no load conditions. The control and overspeed protection characteristics are best revealed by the chordwise force coefficient $C_C$ (also referred to as the suction coefficient).

Positive values of $C_C$ give the blade tip its power producing characteristics and negative values its braking power. To control power, the $C_C$ should decrease monotonically as the aileron deflection is increased over a range of angles-of-attack over which the blade section is expected to operate, namely 0° to about 20° for aileron deflections between 0° and about -40°.

Plots of $C_C$ for both the plain and balanced aileron as a function of angle-of-attack for aileron deflections from 0° to -40° are shown in figure 8.

On a rotating wind turbine rotor, the outboard portion of each blade generally operate in the attached flow condition where the angles-of-attack are normally less than 20°. In the range from $\alpha = 0°$ to about 20° the $C_C$ curves for the plain and balanced ailerons are seen to have similar shapes for most aileron deflections. The notable feature of interest for control purposes is that as the aileron is deflected, the $C_C$ versus $\alpha$ curve shifts to more negative values in a systematic manner after the deflection moves beyond -5°. Between 0° and -5° of deflection, there is little separation between the curves for both ailerons, thereby suggesting that ailerons are not very effective as power control devices in this range. However for aileron deflections between -5° and -25°, the separations between the $C_C$ versus $\alpha$ curves for larger aileron deflections are more systematic (i.e. no crossing of the curves) for the plain ailerons than for the balanced ailerons. It is this regular separation with increased deflection that gives the plain aileron the more desirable power controlling characteristics. For aileron deflections beyond -25°, the $C_C$ versus $\alpha$ curves for both ailerons are well separated, and the separations are more or less constant.

Beyond $\alpha = 20°$ for $\delta_a$'s up to -40°, the $C_C$ curves are of no practical interest because the aileron control sections of the rotor blade do not operate in this $\alpha$ range except during the startup or shutdown transients. However, for braking a wind turbine under no load condition, negative $C_C$ values are desired for all $\alpha$'s up to 90°. The more negative $C_C$ is, the higher is the braking force and the more effective the ailerons are as brakes.

In figure 9, it is seen that for $\delta_a = -90°$ $C_C$ has sizeable negative values for $\alpha$'s less than about 30°. Above 30°, $C_C$ becomes positive for both ailerons. However, for the plain aileron $C_C$ decreases and becomes slightly negative for increasing $\alpha$; whereas, for the balanced aileron, the $C_C$ remains positive at $\alpha$'s greater than 30°. It is this characteristic that makes the balanced aileron less desirable as a braking device. Whether or not a free wheeling rotor under no load is prevented from overspeeding and slowed to a complete stop or to a low equilibrium depends on the balance between the chordwise braking forces produced by the ailerons on the blade tip section and the power producing forces of the span inboard of the ailerons. It is known from analysis and field tests of the plain ailerons on the Mod-0 that the existence of positive $C_C$'s at $\alpha$'s below 90° prevents rotors from being slowed to a complete stop and the sizable negative $C_C$ at low $\delta$'s prevented rotor overspeed (ref. 2).

## Effect of Leading Edge Trip Strips

All of the tests, except for two series (tables IX and XI), were run with trip strips on the leading edge. Those two series were run with the as-built leading edge when the blade was equipped with the balanced aileron. In figure 10 are plotted the $C_L$, $C_D$, and $C_C$ for the cases of 0° and -90° aileron deflection, with and without trip strips and with and without vortex generators (discussed in the next section). A study of these data shows that the trip strips produce a slight and largely negligible effect on the $C_L$, $C_D$, and $C_C$ for all angles-of-attack beyond about 5°. At alphas below 5° the effects are not negligible primarily because the values of $C_L$, $C_D$, and $C_C$ are small to begin with. The leading edge condition had no effect on the $C_C$ when the aileron was deflected to -90°, (fig. 10(d)). Hence, for most engineering calculations, it would be safe to assume the trip strips produce no significant changes in these aerodynamic quantities.

## Effects of the Vortex Generators

The effects of the Vortex Generators (VGs) on $C_L$, $C_D$, and $C_C$ for various angles-of-attack and zero aileron deflection are also shown in figure 10. These data are for the balanced aileron configuration with and without trip strips, and with and without VGs.

The most prominent effect of the VGs was to increase the $C_L$ which in turn increases the $C_C$. These increases occurred in the $\alpha$ range from 5° to 33°, the maximum increase being 25 percent for the $C_L$, and 56 percent for the $C_C$ at $\alpha = 25°$. The slope of the $C_L$ versus $\alpha$ curve was also increased for $\alpha$s below 20°. These increases are understandable because the VGs are performing the function for which they were designed: namely, to induce the free stream to draw closer to the upper surface of the airfoil at higher angles of attack. On the other hand, the VGs did not increase the drag appreciably (fig. 10(b)), primarily because the boundary layers were turbulent to begin with; thus the VGs did not add measurably to the skin friction. Below $\alpha = 5°$, however, the VGs reduced the $C_L$.

The importance of the increased $C_L$ for $\delta_a = 0$ is the accompanying increase in $C_C$ which would lead to an increase in output power in those sections of the rotor blades that operate in the 10° to 35° angle-of-attack range. This is shown in figure 10(c). These results add support to the Mod-2 test of VGs where it was shown that VGs significantly increased the performance of rotors that use NACA 230XX airfoil (ref. 2). The results reported here suggest that rotors made with NACA 64-618 to 621 airfoils will probably experience a significant increase in performance. For $\delta_a = -90°$, the tabular data (not presented in a figure) shows that VGs did not improve the aerodynamic braking characteristics of the outer blade section.

## Effects of Gaps

The importance of the gaps is the effect they have on (1) the rotor efficiency in winds below rated when the ailerons are not deflected and (2) on the aerodynamic braking in an emergency shutdown when the ailerons are fully deflected. For these reasons testing for the effect of the aileron gaps was focused on the angle-of-attack range 0° to 30° for no aileron deflection (discussed below) and 20° to 60° for an aileron deflection of -90° (not discussed in this report).

In figure 11 are shown the effect of gaps on $C_L$, $C_D$, and $C_C$ versus angle-of-attack for the case when the plain aileron is set at a zero deflection angle. In figure 11(a) it is seen that the $C_L$ is decreased by the open gaps over the entire angle of attack range from 0° to 32°. The maximum decrease of about 0.1 occurred at $\alpha$s below 2.5°. The drag coefficient, on the other hand, was increased by the open gaps up to 11 percent for $\alpha = 10°$, and decreased by up to 7.5 percent from beyond 12° to 26°. After 26°, the gaps had no measurable effect on $C_D$ (not shown). The reason for the crossing of the curves in figure 11(b) is not known.

The chordwise force coefficient (fig. 11(c)), was reduced by the open gaps for angles of attack up to about 20°, beyond which the gaps had no effect. These $C_C$ curves in figure 11(c) show clearly that open gaps will probably reduce the efficiency of a rotor because $C_C$ is directly related to the rotor torque and hence the power. Therefore, it is essential that the aerodynamic efficiency of that section of the blade with the ailerons be maintained at the highest possible efficiency. This can be done by an appropriate design of the ailerons that will eliminate gaps when the ailerons are undeflected.

## Effect of Reynolds Number

The effect of the Reynolds Number, Re, on the blade tip section $C_L$, $C_D$, and $C_C$ are examined here only for the tests with the plain ailerons. The tests were run at two midspan Re values: 0.79 and $1.5\times10^6$. Discussed here are the cases where the leading edge was equipped with trip strips (and no VGs) and the ailerons were deflected to 0° and -90°.

It is seen in Figure 12 that the Re effect on the $C_L$, $C_D$, and $C_C$ was negligible at all angles-of-attack except in the range from about 25° to 50° where the effect is seen to be minor. The minor changes in the $C_L$ and $C_D$ when $\delta = 0°$ are probably of no importance except for the effect they have on the $C_C$. The change in $C_C$, however, does have significance, namely, that an increase in Re changes the plain aileron from an aerodynamic brake (negative $C_C$) to a power producing (positive $C_C$) device. This trend with increasing Re has also been observed in the wind tunnel tests of a NACA 23024 semi span model with plain ailerons (unpublished results). Those tests showed that $C_C$ is negative over all $\alpha$ from 0° to 90° at Re less than 600 000 and as the Re is increased, the $C_C$ values in the $\alpha$ range from about 25° to 45° increase monotonically and become positive. As stated in a preceding section, the most suitable aerodynamic braking device is one which produces sizeable negative $C_C$ for all $\alpha$ from 0° to 90°, preferable with $C_C$ values less than -0.2. Hence, these three-dimensional tests of a full scale semispan blade tip with plain ailerons support the conclusions drawn from the tests of a two-dimensional model. That conclusion is that the plain ailerons on a blade tip operating at Reynolds Numbers over one million will provide a significant amount of aerodynamic braking at $\alpha$ below 25°, but not for $\alpha$ over 25°.

## CONCLUSIONS

The important conclusions to be drawn from these tests are that (1) the plain aileron produced better rotor control and aerodynamic braking characteristics than did the balanced aileron, (2) vortex generators produced a significant increase (up to 19 percent) in the chordwise force coefficient which probably would produce an increase in rotor performance, (3) the gaps between the aileron sections and between the ailerons and the main blade tip section produce some degradation in the aerodynamic lift and an increase in the drag when the ailerons are undeflected, (4) the roughened leading edge produced a negligible effect except on the drag coefficient at low alpha and zero aileron deflections where the drag was increased slightly, and (5) the Reynolds Numbers effect was negligible or minor over the range tested.

## REFERENCES

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2. D.R. Miller and R.D. Corrigan, "Shutdown Characteristics of the Mod-0 Wind Turbine with Aileron Controls", NASA TM-86918, DOE/NASA/20320/61, May 1984.

## APPENDIX A

### AILERON HINGE MOMENT COEFFICIENT

Definition of the aileron hinge moment coefficient is:

$$C_{am} = \frac{M_{am}}{q c_{am}^2 b_a}$$

where $M_{am}$ = hinge moment, ft lbf

$q$ = tunnel dynamic pressure, lbf/ft$^2$

$c_{am}$ = mean chord of the aileron, = 1.153 ft

$b_a$ = length of the aileron section = 20 ft

The hinge Moment, Mam, must be determined using the force $F_{PR}$ measured on the push rod of the aileron actuator linkage system. A relationship between the push rod load and the aileron hinge moment is

$$F_{PR}\ (\text{lbf}) \times C = M'_{am}\ (\text{in lb})$$
$$M'_{am} = 12\ M_{am}$$

where the C is a function of the aileron deflection angle. This calibration is given both graphically and in tabular form on the next page.

# APPENDIX B

## TEST MATRICES

TABLE I. - BLADE TIP-SECTION CONFIGURATIONS TESTED

| Aileron type | Leading edge conditions | Aileron gap condition | Pressure cuff | Angle-of-attack probe | Test objectives |
|---|---|---|---|---|---|
| Plain | Trip strips | Open (as-built) | On | On | 1. Probe calibration<br>2. Surface pres. meas. |
| Plain | | Open (as-built) | | Off | Aerodyn. force and moment coefficients |
| Plain | | All gaps taped | | | Measure the effects of gaps |
| Plain | | Hinge line gap only taped | | | Measure the effects of gaps |
| Balanced | | Open (as-built) | Off | | Aerodyn. force and moment coefficients |
| Balanced | Trip strips with vortex generators | Open (as-built) | Off | | Effects of VGs on aerodyn. force and moments |
| Balanced | Smooth (as-built) | Open (as-built) | Off | | Baseline data to determine effects of L.E. roughness |

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TABLE II. - REFERENCE MATRIX OF DATA TABLES AND TEST CONDITIONS

| Table no. | Run nos. | Nominal tunnel Q,PSF | Trip strips | Aileron gaps | VGS | $\delta_a$ Range | AOA Range |
|---|---|---|---|---|---|---|---|
| III Plain ailerons | 1 | 10.5 | On | Open | Off | 0° | 0° to 90.6° |
| | 2 to 9 | | | | | -5° to -40° | 0° to 36.6° |
| | 10 to 12 | | | | | -60° to -80° | 34.6° to 90.6° |
| | 13 | | | | | -90° | 0° to 90.6° |
| IV Plain ailerons | 1 | 3.2 | | | | 0° | 0° to 40.6° |
| | 13 | 3.2 | | | | -90° | 0° to 90.6° |
| V Plain ailerons | 201 | 10.5 | | All sealed. | | 0° | 0° to 30.6° |
| | 213 | 10.5 | | Only hinge line sealed. | | -90° | 20.6° to 60.6° |
| VI Balanced ailerons | 101 | 3.2 | | Open | | 0° | 0° to 32.6° |
| | 113 | 3.2 | | | | -90° | 0° to 90.6° |
| VII Balanced ailerons | 201 | 3.2 | | | On | -90° | 0° to 90.6° |
| VIII Balanced ailerons | 301 | 10.5 | | | Off | 0° | 0° to 90.6° |
| | 302 to 9 | | | | | -5° to -40° | 0° to 36.6° |
| | 310 to 12 | | | | | -60° to -80° | 34.6° to 90.6° |
| | 313 | | | | | -90° | 0° to 90.6° |
| IX Balanced ailerons | 301 | 3.2 | Off | | | -90° | 0° to 90.6° |
| X Balanced ailerons | 401 | 10.5 | On | | On | 0° | 0° to 90.6° |
| | 402 to 05 | | On | | On | -5° to -20° | 0° to 24.6° |
| | 413 | | On | | On | -90° | 0° to 90.6° |
| XI Balanced ailerons | 501 | | Off | | Off | 0° | 0° to 90.6° |
| | 502 to 05 | | Off | | Off | -5° to -20° | 0° to 24.6° |
| | 513 | | Off | | Off | -90° | 0° to 90.6° |

TABLE III

PLAIN AILERONS 180 RPM* TRIP STRIPS ON AILERON GAPS OPEN VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11.1667 | 90.8717 | .5700 | 0.0000 | .0375 | .0178 | -.0494 | -.0174 | .0376 | .0459 |
| 1 | 10.9411 | 89.4617 | 4.5700 | 0.0000 | .4030 | .0285 | -.0652 | .0037 | .4039 | .1102 |
| 1 | 11.0195 | 89.5821 | 8.5700 | 0.0000 | .7256 | .0494 | -.0839 | .0593 | .7249 | .1482 |
| 1 | 10.8016 | 88.8066 | 12.5700 | 0.0000 | .9619 | .0791 | -.0830 | .1322 | .9561 | .2020 |
| 1 | 10.7473 | 88.6330 | 14.5700 | 0.0000 | 1.0425 | .0971 | -.0986 | .1683 | 1.0334 | .2008 |
| 1 | 10.7410 | 88.5679 | 16.5700 | 0.0000 | 1.0889 | .1213 | -.0911 | .1943 | 1.0782 | .2221 |
| 1 | 10.7027 | 88.5630 | 18.5700 | 0.0000 | 1.1248 | .1458 | -.1073 | .2201 | 1.1127 | .2302 |
| 1 | 10.7802 | 88.9207 | 20.5700 | 0.0000 | 1.1290 | .1786 | -.1082 | .2295 | 1.1198 | .2652 |
| 1 | 10.6653 | 88.4385 | 22.5700 | 0.0000 | 1.0748 | .2369 | -.1229 | .1938 | 1.0834 | .2774 |
| 1 | 10.7353 | 88.8017 | 24.5700 | 0.0000 | 1.0469 | .2866 | -.1396 | .1746 | 1.0713 | .3031 |
| 1 | 10.6368 | 88.4177 | 26.5700 | 0.0000 | 1.0044 | .3320 | -.1512 | .1523 | 1.0468 | .3357 |
| 1 | 10.5207 | 87.9014 | 28.5700 | 0.0000 | .9861 | .3719 | -.1437 | .1450 | 1.0439 | .2824 |
| 1 | 10.6429 | 88.6015 | 30.5700 | 0.0000 | .9354 | .4208 | -.1527 | .1134 | 1.0194 | .3051 |
| 1 | 10.5050 | 87.9296 | 32.5700 | 0.0000 | .9125 | .4751 | -.1586 | .0908 | 1.0247 | .3100 |
| 1 | 10.4203 | 87.5118 | 34.5700 | 0.0000 | .8930 | .5086 | -.1626 | .0879 | 1.0239 | .3101 |
| 1 | 10.3360 | 87.0927 | 36.5700 | 0.0000 | .8478 | .5864 | -.1703 | .0342 | 1.0303 | .3247 |
| 1 | 10.1864 | 86.4765 | 40.5700 | 0.0000 | .8187 | .6594 | -.1817 | .0315 | 1.0507 | .3135 |
| 1 | 9.9537 | 85.7796 | 50.5700 | 0.0000 | .7781 | .8942 | -.2269 | .0331 | 1.1849 | .3689 |
| 1 | 9.8669 | 85.3699 | 60.5700 | 0.0000 | .6701 | 1.0622 | -.2597 | .0618 | 1.2544 | .4577 |
| 1 | 9.6899 | 84.5746 | 70.5700 | 0.0000 | .5079 | 1.2079 | -.2984 | .0772 | 1.3081 | .5271 |
| 1 | 9.5220 | 83.7893 | 80.5700 | 0.0000 | .3295 | 1.3048 | -.3567 | .1113 | 1.3411 | .5516 |
| 1 | 9.4611 | 83.4786 | 90.5700 | 0.0000 | .0979 | 1.3386 | -.3516 | .1112 | 1.3376 | .5715 |
| 2 | 11.1248 | 90.6468 | .5700 | -5.0000 | -.0734 | .0195 | -.0276 | -.0203 | -.0732 | .0184 |
| 2 | 10.9514 | 89.4362 | 4.5700 | -5.0000 | .2147 | .0233 | -.0219 | -.0062 | .2159 | .0381 |
| 2 | 11.1099 | 89.9809 | 8.5700 | -5.0000 | .5737 | .0341 | -.0454 | .0517 | .5724 | .0757 |
| 2 | 10.8183 | 88.8835 | 12.5700 | -5.0000 | .8573 | .0629 | -.0590 | .1252 | .8505 | .1388 |
| 2 | 10.8039 | 88.8640 | 16.5700 | -5.0000 | .9929 | .1024 | -.0828 | .1650 | .9808 | .2025 |
| 2 | 10.8008 | 88.9822 | 20.5700 | -5.0000 | 1.0538 | .1541 | -.0884 | .2260 | 1.0407 | .2321 |
| 2 | 10.6656 | 88.5038 | 24.5700 | -5.0000 | .9785 | .2535 | -.1154 | .1763 | .9953 | .2853 |
| 2 | 10.5741 | 88.1076 | 28.5700 | -5.0000 | .9203 | .3342 | -.1210 | .1467 | .9681 | .2667 |
| 2 | 10.5667 | 88.2041 | 32.5700 | -5.0000 | .8730 | .4407 | -.1410 | .0986 | .9730 | .2990 |
| 2 | 10.3908 | 87.3378 | 36.5700 | -5.0000 | .8155 | .5573 | -.1562 | .0383 | .9870 | .3241 |
| 3 | 11.0204 | 90.1892 | .5700 | -10.0000 | -.2946 | .0357 | .0276 | -.0386 | -.2942 | -.0934 |
| 3 | 10.8864 | 89.1552 | 4.5700 | -10.0000 | .0244 | .0304 | .0192 | -.0283 | .0268 | -.0546 |
| 3 | 11.0043 | 89.4778 | 8.5700 | -10.0000 | .3522 | .0306 | .0005 | .0222 | .3528 | -.0112 |
| 3 | 10.8446 | 88.9724 | 12.5700 | -10.0000 | .6291 | .0410 | .0010 | .0969 | .6229 | .0108 |
| 3 | 10.8718 | 89.1302 | 16.5700 | -10.0000 | .8968 | .0797 | -.0491 | .1794 | .8823 | .1136 |
| 3 | 10.8280 | 89.1283 | 20.5700 | -10.0000 | .9564 | .1280 | -.0600 | .2162 | .9404 | .1810 |
| 3 | 10.7887 | 89.0015 | 24.5700 | -10.0000 | .8993 | .2179 | -.0874 | .1757 | .9085 | .2316 |
| 3 | 10.6720 | 88.4651 | 28.5700 | -10.0000 | .8403 | .2934 | -.0957 | .1442 | .8783 | .2110 |

*Wind tunnel fan speed corresponding to a tunnel Qs in first column

TABLE III

PLAIN AILERONS 180 RPM TRIP STRIPS ON AILERON GAPS OPEN VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 10.6540 | 88.5605 | 32.5700 | -10.0000 | .8043 | .3965 | -.1092 | .0988 | .8913 | .2488 |
| 3 | 10.5171 | 87.8870 | 36.5700 | -10.0000 | .7729 | .4747 | -.1228 | .0793 | .9036 | .2789 |
| 4 | 10.9663 | 89.9364 | .5700 | -15.0000 | -.4516 | .0541 | .0590 | -.0586 | -.4510 | -.1760 |
| 4 | 10.7838 | 88.6811 | 4.5700 | -15.0000 | -.1362 | .0455 | .0533 | -.0562 | -.1322 | -.1342 |
| 4 | 11.0312 | 89.5956 | 8.5700 | -15.0000 | .1652 | .0414 | .0471 | -.0163 | .1696 | -.1119 |
| 4 | 10.8494 | 88.9891 | 12.5700 | -15.0000 | .4622 | .0445 | .0390 | .0571 | .4608 | -.0750 |
| 4 | 10.8153 | 88.8786 | 16.5700 | -15.0000 | .7285 | .0598 | .0218 | .1504 | .7153 | -.0120 |
| 4 | 10.8651 | 89.2624 | 20.5700 | -15.0000 | .8806 | .1071 | -.0324 | .2091 | .8621 | .0978 |
| 4 | 10.9069 | 89.4716 | 24.5700 | -15.0000 | .8075 | .1854 | -.0365 | .1672 | .8115 | .1610 |
| 4 | 10.7272 | 88.7182 | 28.5700 | -15.0000 | .7683 | .2616 | -.0577 | .1377 | .7998 | .1557 |
| 4 | 10.6830 | 88.6555 | 32.5700 | -15.0000 | .7499 | .3651 | -.0820 | .0960 | .8285 | .2064 |
| 4 | 10.4875 | 87.7472 | 36.5700 | -15.0000 | .6661 | .4537 | -.0904 | .0325 | .8052 | .2272 |
| 5 | 10.9505 | 89.8546 | .5700 | -20.0000 | -.5358 | .0711 | .0779 | -.0765 | -.5351 | -.2067 |
| 5 | 10.7890 | 88.6988 | 4.5700 | -20.0000 | -.2709 | .0640 | .0883 | -.0854 | -.2650 | -.2008 |
| 5 | 10.9083 | 89.0592 | 8.5700 | -20.0000 | .0198 | .0598 | .0872 | -.0562 | .0285 | -.1904 |
| 5 | 10.8538 | 88.9732 | 12.5700 | -20.0000 | .3095 | .0565 | .0749 | .0122 | .3144 | -.1756 |
| 5 | 10.8809 | 89.1571 | 16.5700 | -20.0000 | .5613 | .0641 | .0649 | .0986 | .5562 | -.1148 |
| 5 | 10.9215 | 89.4809 | 20.5700 | -20.0000 | .7530 | .0920 | .0323 | .1784 | .7373 | -.0227 |
| 5 | 10.7906 | 89.0255 | 24.5700 | -20.0000 | .7171 | .1649 | .0036 | .1482 | .7208 | .0842 |
| 5 | 10.7757 | 88.8758 | 28.5700 | -20.0000 | .6831 | .2336 | -.0257 | .1215 | .7116 | .0912 |
| 5 | 10.7742 | 89.0020 | 32.5700 | -20.0000 | .6695 | .3210 | -.0470 | .0899 | .7370 | .1493 |
| 5 | 10.5877 | 88.1791 | 36.5700 | -20.0000 | .6340 | .3965 | -.0571 | .0593 | .7454 | .1846 |
| 6 | 10.9291 | 89.7568 | .5700 | -25.0000 | -.6397 | .0884 | .0960 | -.0948 | -.6388 | -.2446 |
| 6 | 10.7340 | 88.5093 | 4.5700 | -25.0000 | -.3821 | .0806 | .1043 | -.1107 | -.3744 | -.2441 |
| 6 | 10.8333 | 88.7659 | 8.5700 | -25.0000 | -.0803 | .0736 | .1046 | -.0848 | -.0684 | -.2441 |
| 6 | 10.8474 | 88.9320 | 12.5700 | -25.0000 | .1988 | .0687 | .1034 | -.0238 | .2089 | -.2288 |
| 6 | 10.8954 | 89.2117 | 16.5700 | -25.0000 | .4545 | .0747 | .0963 | .0581 | .4569 | -.1930 |
| 6 | 10.9093 | 89.3976 | 20.5700 | -25.0000 | .6578 | .0956 | .0716 | .1416 | .6494 | -.1458 |
| 6 | 10.8675 | 89.3236 | 24.5700 | -25.0000 | .6732 | .1586 | .0342 | .1356 | .6782 | -.0113 |
| 6 | 10.7260 | 88.6808 | 28.5700 | -25.0000 | .5540 | .2148 | .0233 | .0763 | .5893 | -.0200 |
| 6 | 10.7792 | 89.0567 | 32.5700 | -25.0000 | .5597 | .2950 | -.0006 | .0527 | .6305 | .0543 |
| 6 | 10.6060 | 88.2493 | 36.5700 | -25.0000 | .5337 | .3624 | -.0138 | .0269 | .6446 | .0999 |
| 7 | 10.8719 | 89.4816 | .5700 | -30.0000 | -.7625 | .1096 | .1173 | -.1172 | -.7613 | -.2795 |
| 7 | 10.7219 | 88.4424 | 4.5700 | -30.0000 | -.4928 | .0978 | .1223 | -.1368 | -.4835 | -.2811 |
| 7 | 10.7832 | 88.5652 | 8.5700 | -30.0000 | -.1912 | .0863 | .1224 | -.1138 | -.1762 | -.2706 |
| 7 | 10.7876 | 88.6615 | 12.5700 | -30.0000 | .0861 | .0827 | .1227 | -.0619 | .1020 | -.2717 |
| 7 | 10.8898 | 89.1745 | 16.5700 | -30.0000 | .3556 | .0847 | .1110 | .0202 | .3650 | -.240[illegible] |
| 7 | 10.9031 | 89.3463 | 20.5700 | -30.0000 | .5748 | .1011 | .0949 | .1073 | .5736 | -.2173 |
| 7 | 10.8750 | 89.3709 | 24.5700 | -30.0000 | .6428 | .1571 | .0505 | .1244 | .6500 | -.0874 |
| 7 | 10.7345 | 88.7215 | 28.5700 | -30.0000 | .5134 | .2126 | .0502 | .0588 | .5526 | -.1101 |

TABLE III

PLAIN AILERONS 180 RPM TRIP STRIPS ON AILERON GAPS OPEN VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 10.7824 | 89.0708 | 32.5700 | -30.0000 | .4701 | .2778 | .0389 | .0189 | .5458 | -.0714 |
| 7 | 10.6141 | 88.2597 | 36.5700 | -30.0000 | .4307 | .3489 | .0303 | -.0236 | .5538 | -.0225 |
| 8 | 10.8838 | 89.4754 | .5700 | -35.0000 | -.8935 | .1346 | .1359 | -.1435 | -.8921 | -.3456 |
| 8 | 10.6438 | 88.0759 | 4.5700 | -35.0000 | -.5984 | .1172 | .1417 | -.1645 | -.5871 | -.3087 |
| 8 | 10.8026 | 88.6328 | 8.5700 | -35.0000 | -.3174 | .1039 | .1461 | -.1501 | -.2984 | -.3231 |
| 8 | 10.7344 | 88.4418 | 12.5700 | -35.0000 | -.0355 | .0968 | .1419 | -.1022 | -.0135 | -.3231 |
| 3 | 10.8830 | 89.1528 | 16.5700 | -35.0000 | .2295 | .0977 | .1355 | -.0282 | .2478 | -.2883 |
| 8 | 10.9060 | 89.3876 | 20.5700 | -35.0000 | .4893 | .1091 | .1116 | .0697 | .4964 | -.2649 |
| 8 | 10.8656 | 89.3164 | 24.5700 | -35.0000 | .6888 | .1617 | .0507 | .1394 | .6936 | -.1183 |
| 8 | 10.7293 | 88.7030 | 28.5700 | -35.0000 | .5557 | .2223 | .0415 | .0705 | .5943 | -.1241 |
| 8 | 10.7389 | 88.8711 | 32.5700 | -35.0000 | .4626 | .2951 | .0422 | .0003 | .5487 | -.1150 |
| 8 | 10.5855 | 88.1056 | 36.5700 | -35.0000 | .3851 | .3528 | .0490 | -.0539 | .5195 | -.1042 |
| 9 | 10.8296 | 89.2474 | .5700 | -40.0000 | -.9914 | .1658 | .1601 | -.1756 | -.9897 | -.3970 |
| 9 | 10.6435 | 88.0870 | 4.5700 | -40.0000 | -.7250 | .1447 | .1628 | -.2020 | -.7112 | -.3632 |
| 9 | 10.8206 | 88.6958 | 8.5700 | -40.0000 | -.4543 | .1262 | .1648 | -.1925 | -.4304 | -.3741 |
| 9 | 10.6783 | 88.2150 | 12.5700 | -40.0000 | -.1733 | .1187 | .1657 | -.1535 | -.1433 | -.3768 |
| 9 | 10.8241 | 88.9203 | 16.5700 | -40.0000 | .1084 | .1124 | .1558 | -.0768 | .1359 | -.3237 |
| 9 | 10.9025 | 89.3667 | 20.5700 | -40.0000 | .400[illegible] | .1146 | .1352 | .0335 | .4156 | -.3110 |
| 9 | 10.7720 | 88.9276 | 24.5700 | -40.0000 | .6222 | .1548 | .0700 | .1180 | .6302 | -.1675 |
| 9 | 10.7743 | 88.8961 | 28.5700 | -40.0000 | .6040 | .2246 | .0288 | .0916 | .6379 | -.1079 |
| 9 | 10.7230 | 88.8066 | 32.5700 | -40.0000 | .5170 | .3159 | .0174 | .0121 | .6058 | -.0832 |
| 9 | 10.6559 | 88.4081 | 36.5700 | -40.0000 | .4705 | .3709 | .0217 | -.0176 | .5988 | -.0664 |
| 10 | 10.6430 | 88.4402 | 34.5700 | -60.0000 | .6191 | .3243 | -.0085 | .0842 | .6939 | -.0077 |
| 10 | 10.4938 | 87.7471 | 40.5700 | -60.0000 | .5034 | .4503 | -.0174 | -.0147 | .6752 | -.0085 |
| 10 | 10.2728 | 87.1575 | 50.5700 | -60.0000 | .4347 | .6350 | -.0233 | -.0675 | .7666 | -.0747 |
| 10 | 10.0914 | 86.3210 | 60.5700 | -60.0000 | .3[illegible]8 | .7412 | -.0495 | -.0622 | .8159 | -.0447 |
| 10 | 10.0160 | 85.9933 | 70.5700 | -60.0000 | .2336 | .8340 | -.0661 | -.0572 | .8642 | -.0634 |
| 10 | 9.8597 | 85.2379 | 80.5700 | -60.0000 | .0889 | .8981 | -.0891 | -.0595 | .9005 | -.1070 |
| 10 | 9.8787 | 85.2633 | 90.5700 | -60.0000 | .0011 | .9324 | -.1361 | .0103 | .9323 | -.0226 |
| 11 | 10.6297 | 88.3418 | 34.5700 | -70.0000 | .6363 | .3327 | -.0165 | .0871 | .7127 | -.0009 |
| 11 | 10.5295 | 87.9118 | 40.5700 | -70.0000 | .5530 | .4559 | -.0260 | .0134 | .7166 | .0254 |
| 11 | 10.2330 | 86.9792 | 50.5700 | -70.0000 | .4300 | .6239 | -.0226 | -.0642 | .7550 | -.0706 |
| 11 | 10.0301 | 86.0582 | 60.5700 | -70.0000 | .3530 | .7364 | -.0496 | -.0544 | .8148 | -.0585 |
| 11 | 9.9940 | 85.8839 | 70.5700 | -70.0000 | .2506 | .8328 | -.0683 | -.0407 | .8688 | -.0559 |
| 11 | 9.9286 | 85.5401 | 80.5700 | -70.0000 | .1388 | .9157 | -.1105 | -.0131 | .9261 | -.0931 |
| 11 | 9.7060 | 84.5099 | 90.5700 | -70.0000 | -.0026 | .9561 | -.1366 | .0069 | .9561 | -.0977 |
| 12 | 10.5900 | 88.1978 | 34.5700 | -80.0000 | .6261 | .3424 | -.0094 | .0733 | .7098 | -.0465 |
| 12 | 10.5723 | 88.0870 | 40.5700 | -80.0000 | .5865 | .4564 | -.0345 | .0348 | .7424 | .0432 |
| 12 | 10.2086 | 86.8564 | 50.5700 | -80.0000 | .4625 | .6262 | -.0312 | -.0404 | .7774 | -.0549 |
| 12 | 10.0539 | 86.1641 | 60.5700 | -80.0000 | .3603 | .7389 | -.0508 | -.0492 | .8206 | -.0341 |

TABLE III

PLAIN AILERONS 180 RPM TRIP STRIPS ON AILERON GAPS OPEN VORTEX GENERETORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 10.0147 | 85.9320 | 70.5700 | -80.0000 | .2474 | .8152 | -.0667 | -.0378 | .8511 | -.0389 |
| 12 | 9.8907 | 85.3774 | 80.5700 | -80.0000 | .1482 | .9069 | -.1102 | -.0024 | .9189 | -.1008 |
| 12 | 9.8132 | 84.9714 | 90.5700 | -80.0000 | .0326 | .9667 | -.1462 | .0422 | .9663 | -.0696 |
| 13 | 10.3499 | 87.2048 | .5700 | -90.0000 | -1.4865 | .4494 | .2279 | -.4642 | -1. 820 | -.7712 |
| 13 | 10.1122 | 85.8189 | 4.5700 | -90.0000 | -1.3122 | .4446 | .2296 | -.5478 | -1.2726 | -.7738 |
| 13 | 10.3098 | 86.5816 | 8.5700 | -90.0000 | -1.0974 | .4294 | .2403 | -.5882 | -1.0212 | -.7719 |
| 13 | 10.3105 | 86.6608 | 12.5700 | -90.0000 | -.8937 | .4318 | .2428 | -.6159 | -.7783 | -.7836 |
| 13 | 10.2910 | 86.6948 | 14.5700 | -90.0000 | -.7676 | .4201 | .2352 | -.5997 | -.6372 | -.7679 |
| 13 | 10.4125 | 87.1809 | 16.5700 | -90.0000 | -.6560 | .4146 | .2330 | -.5845 | -.5105 | -.7480 |
| 13 | 10.4403 | 87.3877 | 18.5700 | -90.0000 | -.5575 | .4067 | .2293 | -.5630 | -.3989 | -.7490 |
| 13 | 10.5206 | 87.8081 | 20.5700 | -90.0000 | -.4555 | .3950 | .2281 | -.5299 | -.2876 | -.7296 |
| 13 | 10.5309 | 87.8538 | 22.5700 | -90.0000 | -.3462 | .3931 | .2208 | -.4959 | -.1688 | -.7217 |
| 13 | 10.6045 | 89.1991 | 24.5700 | -90.0000 | -.2017 | .3834 | .2100 | -.4325 | -.0240 | -.6839 |
| 13 | 10.5955 | 88.2227 | 26.5700 | -90.0000 | .0058 | .3663 | .1662 | -.3251 | .1690 | -.5510 |
| 13 | 10.5897 | 88.0417 | 28.5700 | -90.0000 | .1651 | .3544 | .1285 | -.2322 | .3145 | -.5045 |
| 13 | 10.7332 | 88.9485 | 30.5700 | -90.0000 | .3490 | .3426 | .0800 | -.1175 | .4748 | -.3519 |
| 13 | 10.6761 | 88.6021 | 32.5700 | -90.0000 | .4954 | .3454 | .0402 | -.0244 | .6035 | -.2172 |
| 13 | 10.5891 | 88.2025 | 34.5700 | -90.0000 | .5685 | .3559 | .0157 | .0295 | .6701 | -.1306 |
| 13 | 10.5863 | 88.1106 | 36.5700 | -90.0000 | .6177 | .3713 | -.0160 | .0698 | .7173 | -.0109 |
| 13 | 10.5033 | 87.7707 | 40.5700 | -90.0000 | .6094 | .4465 | -.0374 | .0571 | .7533 | .0502 |
| 13 | 10.2397 | 86.9866 | 50.5700 | -90.0000 | .4758 | .6356 | -.0318 | -.0362 | .7932 | -.0519 |
| 13 | 10.0968 | 86.3131 | 60.5700 | -90.0000 | .3796 | .7388 | -.0585 | -.0324 | .8300 | -.0406 |
| 13 | 9.9996 | 85.8578 | 70.5700 | -90.0000 | .2452 | .8096 | -.0632 | -.0381 | .8450 | -.0513 |
| 13 | 9.8131 | 85.0197 | 80.5700 | -90.0000 | .1413 | .8897 | -.1068 | -.0063 | .9009 | -.0931 |
| 13 | 9.7702 | 84.7587 | 90.5700 | -90.0000 | .0523 | .9570 | -.1498 | .0618 | .9564 | -.0519 |

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TABLE IV

PLAIN AILERONS 100 RPM* TRIP STRIPS ON AILERON GAPS OPEN VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.3909 | 50.0823 | .5700 | 0.0000 | .0938 | .0187 | -.0492 | -.0178 | .0940 | .0580 |
| 1 | 3.2772 | 48.8286 | 8.5700 | 0.0000 | .7431 | .0499 | -.0845 | .0614 | .7422 | .1165 |
| 1 | 3.2804 | 48.8268 | 12.5700 | 0.0000 | .9711 | .0798 | -.0990 | .1335 | .9652 | .1638 |
| 1 | 3.3064 | 49.0752 | 14.5700 | 0.0000 | 1.0313 | .1021 | -.0896 | .1606 | 1.0239 | .1596 |
| 1 | 3.2367 | 48.5445 | 16.5700 | 0.0000 | 1.0885 | .1217 | -.0886 | .1938 | 1.0780 | .2215 |
| 1 | 3.2336 | 48.5344 | 18.5700 | 0.0000 | 1.1460 | .1530 | -.0960 | .2199 | 1.1351 | .2367 |
| 1 | 3.3086 | 49.0876 | 20.5700 | 0.0000 | 1.1162 | .1841 | -.1069 | .2198 | 1.1097 | .2549 |
| 1 | 3.3117 | 49.2133 | 22.5700 | 0.0000 | 1.0978 | .2480 | -.1118 | .1924 | 1.1089 | .2876 |
| 1 | 3.3121 | 49.2013 | 24.5700 | 0.0000 | 1.0589 | .2938 | -.1329 | .1731 | 1.0851 | .3157 |
| 1 | 3.2742 | 48.8876 | 26.5700 | 0.0000 | 1.0577 | .3560 | -.1434 | .1547 | 1.1052 | .4325 |
| 1 | 3.1858 | 48.1953 | 28.5700 | 0.0000 | .9561 | .3909 | -.1506 | .1139 | 1.0266 | .2179 |
| 1 | 3.2599 | 48.9262 | 30.5700 | 0.0000 | .8848 | .4829 | -.1676 | .0342 | 1.0074 | .2849 |
| 1 | 3.1752 | 48.1857 | 36.5700 | 0.0000 | .8460 | .6087 | -.1760 | .0152 | 1.0421 | .3776 |
| 1 | 3.1405 | 47.8822 | 40.5700 | 0.0000 | .8222 | .6829 | -.1857 | .0160 | 1.0687 | .3434 |
| 13 | 3.1600 | 48.3070 | .5700 | -90.0000 | -1.4121 | .4388 | .2016 | -.4528 | -1.4076 | -.8304 |
| 13 | 3.1200 | 47.5938 | 8.5700 | -90.0000 | -1.0967 | .4524 | .2315 | -.6107 | -1.0171 | -.9289 |
| 13 | 3.1542 | 47.8882 | 12.5700 | -90.0000 | -.8955 | .4429 | .2375 | -.6272 | -.7776 | -.9225 |
| 13 | 3.1449 | 47.8473 | 14.5700 | -90.0000 | -.7663 | .4435 | .2283 | -.6220 | -.6301 | -.9407 |
| 13 | 3.1920 | 48.2001 | 16.5700 | -90.0000 | -.6422 | .4162 | .2232 | -.5821 | -.4969 | -.8428 |
| 13 | 3.1592 | 47.9760 | 18.5700 | -90.0000 | -.5451 | .4138 | .2220 | -.5659 | -.3849 | -.8941 |
| 13 | 3.1882 | 48.2157 | 20.5700 | -90.0000 | -.4405 | .4082 | .2058 | -.5370 | -.2690 | -.8630 |
| 13 | 3.1854 | 48.2292 | 22.5700 | -90.0000 | -.3413 | .4107 | .2235 | -.5103 | -.1576 | -.8790 |
| 13 | 3.2616 | 48.8343 | 24.5700 | -90.0000 | -.1947 | .3905 | .1911 | -.4361 | -.0147 | -.7988 |
| 13 | 3.1834 | 48.2327 | 26.5700 | -90.0000 | .0012 | .3936 | .1746 | -.3515 | .1771 | -.6823 |
| 13 | 3.2378 | 48.5394 | 28.5700 | -90.0000 | .2116 | .3519 | .0982 | -.2079 | .3542 | -.6752 |
| 13 | 3.2776 | 49.0415 | 30.5700 | -90.0000 | .4820 | .3441 | .0324 | -.0512 | .5900 | -.3266 |
| 13 | 3.1882 | 48.2666 | 36.5700 | -90.0000 | .5769 | .4255 | -.0270 | .0020 | .7168 | -.0851 |
| 13 | 3.1931 | 48.2701 | 40.5700 | -90.0000 | .5629 | .4770 | -.0371 | .0038 | .7378 | -.0924 |
| 13 | 3.1754 | 48.4283 | 45.5700 | -90.0000 | .4933 | .5533 | -.0439 | -.0351 | .7404 | -.0605 |
| 13 | 3.1582 | 48.2263 | 50.5700 | -90.0000 | .4615 | .6437 | -.0253 | -.0523 | .7903 | -.1510 |
| 13 | 3.0377 | 47.2875 | 60.5700 | -90.0000 | .3632 | .7484 | -.0632 | -.0514 | .8303 | -.1107 |
| 13 | 3.0467 | 47.3278 | 70.5700 | -90.0000 | .2428 | .8319 | -.0530 | -.0477 | .8653 | -.1293 |
| 13 | 2.9685 | 46.7102 | 80.5700 | -90.0000 | .1520 | .9387 | -.1250 | -.0038 | .9509 | -.2381 |
| 13 | 2.9631 | 46.6257 | 90.5700 | -90.0000 | .0474 | .9996 | -.1507 | .0573 | .9991 | -.1627 |

*Tunnel fan speed corresponding to the tunnel Q in the first column

TABLE V

PLAIN AILERONS 180 RPM TRIP STRIPS ON AILERON GAPS SEALED VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 201 | 10.8269 | 89.5874 | .5700 | 0.0000 | .1358 | .0161 | -.0707 | -.0148 | .1360 | .0281 |
| 201 | 10.7327 | 89.2069 | 4.5700 | 0.0000 | .4539 | .0262 | -.0692 | .0101 | .4545 | .0130 |
| 201 | 10.7855 | 89.4012 | 8.5700 | 0.0000 | .7798 | .0470 | -.0749 | .0697 | .7781 | .0090 |
| 201 | 10.6519 | 89.7958 | 10.5700 | 0.0000 | .9338 | .0583 | -.0834 | .1140 | .9286 | .0364 |
| 201 | 10.6825 | 88.9667 | 12.5700 | 0.0000 | 1.0452 | .0840 | -.1109 | .1455 | 1.0385 | .0348 |
| 201 | 10.6142 | 88.7004 | 14.5700 | 0.0000 | 1.1119 | .1043 | -.1156 | .1788 | 1.1024 | .1107 |
| 201 | 10.5603 | 88.4377 | 16.5700 | 0.0000 | 1.1521 | .1270 | -.1167 | .2068 | 1.1405 | .1090 |
| 201 | 10.5470 | 88.3681 | 18.5700 | 0.0000 | 1.1726 | .1533 | -.1179 | .2281 | 1.1604 | .0727 |
| 201 | 10.5162 | 88.2322 | 20.5700 | 0.0000 | 1.1653 | .1900 | -.1222 | .2316 | 1.1578 | .1019 |
| 201 | 10.6233 | 88.8668 | 22.5700 | 0.0000 | 1.1198 | .2509 | -.1392 | .1981 | 1.1304 | .1020 |
| 201 | 10.4672 | 88.1611 | 24.5700 | 0.0000 | 1.0605 | .2942 | -.1481 | .1734 | 1.0868 | .1164 |
| 201 | 10.3919 | 87.8089 | 26.5700 | 0.0000 | 1.0124 | .3370 | -.1533 | .1514 | 1.0562 | .1144 |
| 201 | 10.3537 | 87.6493 | 28.5700 | 0.0000 | .9991 | .3823 | -.1653 | .1420 | 1.0603 | .1182 |
| 201 | 10.2735 | 87.2852 | 30.5700 | 0.0000 | .9664 | .4412 | -.1574 | .1116 | 1.0565 | .1231 |

TABLE V

PLAIN AILERONS 180 RPM TRIP STRIPS ON ONLY HINGE LINE SEALED VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 213 | 10.3448 | 87.6086 | 20.5700 | -90.0000 | -.4791 | .4024 | .2330 | -.5450 | -.3071 | -.6525 |
| 213 | 10.5587 | 88.3790 | 28.5700 | -90.0000 | .1455 | .3530 | .1333 | -.2404 | .2966 | -.4138 |
| 213 | 10.3885 | 87.4902 | 32.5700 | -90.0000 | .4558 | .3432 | .0492 | -.0480 | .5716 | -.1842 |
| 213 | 10.3496 | 87.3894 | 36.5700 | -90.0000 | .6387 | .3716 | -.0157 | .0821 | .7344 | .0029 |
| 213 | 10.2892 | 86.9940 | 40.5700 | -90.0000 | .6141 | .4518 | -.0385 | .0562 | .7604 | .0742 |
| 213 | 10.2306 | 86.7544 | 45.5700 | -90.0000 | .5350 | .5436 | -.0261 | .0015 | .7627 | .0211 |
| 213 | 10.1295 | 86.2761 | 50.5700 | -90.0000 | .4767 | .6281 | -.0376 | -.0307 | .7879 | -.0014 |
| 213 | 10.0119 | 85.6881 | 55.5700 | -90.0000 | .4331 | .6937 | -.0428 | -.0350 | .8171 | .0065 |
| 213 | 9.8719 | 84.9780 | 60.5700 | -90.0000 | .3838 | .7596 | -.0519 | -.0390 | .8502 | -.0005 |

TABLE VI

BALANCED AILERONS 100 RPM TRIP STRIPS ON AILERON GAPS OPEN VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 101 | 3.3139 | 48.9430 | .5700 | 0.0000 | .2431 | .0219 | -.0592 | -.0195 | .2433 | .0000 |
| 101 | 3.2739 | 48.6054 | 4.5700 | 0.0000 | .5403 | .0334 | -.0716 | .0098 | .5413 | .0000 |
| 101 | 3.3181 | 49.0096 | 8.5700 | 0.0000 | .8141 | .0599 | -.0934 | .0621 | .8140 | .0000 |
| 101 | 3.2841 | 48.7834 | 10.5700 | 0.0000 | .8990 | .0695 | -.0926 | .0966 | .8965 | .0000 |
| 101 | 3.2278 | 48.3213 | 12.5700 | 0.0000 | .9726 | .0890 | -.0881 | .1248 | .9687 | .0000 |
| 101 | 3.2827 | 48.7602 | 14.5700 | 0.0000 | 1.0491 | .1118 | -.0920 | .1557 | 1.0435 | .0000 |
| 101 | 3.2692 | 48.6597 | 16.5700 | 0.0000 | 1.0885 | .1331 | -.1032 | .1828 | 1.0813 | .0000 |
| 101 | 3.2515 | 48.5776 | 20.5700 | 0.0000 | 1.1271 | .1892 | -.0958 | .2189 | 1.1218 | .0000 |
| 101 | 3.2419 | 48.7843 | 22.5700 | 0.0000 | 1.0429 | .2501 | -.0895 | .1694 | 1.0590 | .0000 |
| 101 | 3.2081 | 48.3847 | 24.5700 | 0.0000 | 1.0145 | .2892 | -.1036 | .1588 | 1.0429 | .0000 |
| 101 | 3.1995 | 48.2422 | 26.5700 | 0.0000 | .9746 | .3278 | -.1093 | .1428 | 1.0183 | .0000 |
| 101 | 3.1574 | 47.8155 | 28.5700 | 0.0000 | .9175 | .4016 | -.1478 | .0861 | .9979 | .0000 |
| 101 | 3.1105 | 47.3488 | 32.5700 | 0.0000 | .8284 | .5105 | -.1557 | .0158 | .9729 | .0000 |
| 113 | 3.1123 | 47.4557 | .5700 | -90.0000 | -1.3483 | .4740 | .2208 | -.4874 | -1.3435 | -.8274 |
| 113 | 3.1251 | 47.4891 | 4.5700 | -90.0000 | -1.1622 | .4776 | .2122 | -.5687 | -1.1204 | -.8200 |
| 113 | 3.1156 | 47.5059 | 8.5700 | -90.0000 | -.9396 | .4747 | .2054 | -.6094 | -.8584 | -.8188 |
| 113 | 3.1105 | 47.4957 | 10.5700 | -90.0000 | -.8209 | .4831 | .2290 | -.6255 | -.7183 | -.8206 |
| 113 | 3.1018 | 47.3915 | 12.5700 | -90.0000 | -.6971 | .4792 | .2165 | -.6194 | -.5761 | -.8192 |
| 113 | 3.1052 | 47.4152 | 14.5700 | -90.0000 | -.5928 | .4799 | .1929 | -.6136 | -.4530 | -.8407 |
| 113 | 3.1426 | 47.7212 | 16.5700 | -90.0000 | -.4479 | .4657 | .1809 | -.5741 | -.2965 | -.7348 |
| 113 | 3.1359 | 47.6952 | 20.5700 | -90.0000 | -.2299 | .4595 | .1673 | -.5110 | -.0538 | -.7534 |
| 113 | 3.1812 | 48.3070 | 22.5700 | -90.0000 | -.1335 | .4555 | .1858 | -.4718 | .0515 | -.7505 |
| 113 | 3.1679 | 48.0798 | 24.5700 | -90.0000 | .0743 | .4331 | .1467 | -.3629 | .2477 | -.6149 |
| 113 | 3.1627 | 47.9590 | 26.5700 | -90.0000 | .3044 | .4266 | .0875 | -.2454 | .4631 | -.5003 |
| 113 | 3.1619 | 47.8328 | 28.5700 | -90.0000 | .5026 | .4172 | .0145 | -.1260 | .6410 | -.3913 |
| 113 | 3.1344 | 47.4915 | 32.5700 | -90.0000 | .8284 | .4395 | -.0844 | .0756 | .9348 | .0582 |
| 113 | 3.0691 | 46.8360 | 36.5700 | -90.0000 | .7953 | .5131 | -.0908 | .0618 | .9444 | .0882 |
| 113 | 3.0452 | 46.6456 | 40.5700 | -90.0000 | .7379 | .5930 | -.1027 | .0294 | .9462 | .0956 |
| 113 | 3.0290 | 46.4434 | 50.5700 | -90.0000 | .6420 | .7827 | -.1177 | -.0013 | 1.0124 | .0802 |
| 113 | 2.9482 | 45.7928 | 60.5700 | -90.0000 | .5193 | [illegible] | -.1310 | -.0019 | 1.0603 | .0488 |
| 113 | 2.9346 | 45.6591 | 70.5700 | -90.0000 | .3561 | [illegible] | -.1544 | -.0034 | 1.0802 | .0643 |
| 113 | 2.8967 | 45.3672 | 80.5700 | -90.0000 | .2603 | [illegible] | -.2883 | .0629 | 1.2100 | .0436 |
| 113 | 2.9137 | 45.5129 | 90.5700 | -90.0000 | .0040 | 1.0877 | -.2075 | .0148 | 1.0876 | .0484 |

TABLE VII

BALANCED AILERONS 100 RPM TRIP STRIPS ON AILERON GAPS OPEN VORTEX GENERATORS ON

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 201 | 3.[illegible] | 47.3851 | .5700 | -90.0000 | -1.4116 | .4740 | .2078 | -.4881 | -1.4068 | -.8804 |
| 201 | 3.0633 | 47.2082 | 4.5700 | -90.0000 | -1.1645 | .4723 | .2130 | -.5636 | -1.1232 | -.8401 |
| 201 | 3.0255 | 46.8413 | 8.5700 | -90.0000 | -.9293 | .4745 | .2240 | -.6077 | -.8482 | -.8522 |
| 201 | 3.0434 | 46.9383 | 10.5700 | -90.0000 | -.8173 | .4786 | .2132 | -.6204 | -.7157 | -.8373 |
| 201 | 3.0068 | 46.5141 | 12.5700 | -90.0000 | -.6965 | .4597 | .2113 | -.6002 | -.5798 | -.8184 |
| 201 | 3.0253 | 46.6[illegible]34 | 14.5700 | -90.0000 | -.5710 | .4991 | .2216 | -.6267 | -.4271 | -.8310 |
| 201 | 3.1494 | 47.[illegible]71 | 16.5700 | -90.0000 | -.4697 | .4852 | .2156 | -.5990 | -.3118 | -.8164 |
| 201 | 3.0042 | 46.3349 | 18.5700 | -90.0000 | -.3581 | .4760 | .1976 | -.5653 | -.1[illegible]9 | -.8237 |
| 201 | 3.0299 | 46.4640 | 20.5700 | -90.0000 | -.2071 | .4769 | .1860 | -.5193 | -.0264 | -.7613 |
| 201 | 2.9905 | 46.1330 | 22.5700 | -90.0000 | -.0862 | .4751 | .1787 | -.4718 | .1027 | -.7594 |
| 201 | 3.0021 | 46.2141 | 24.5700 | -90.0000 | .1081 | .4682 | .1650 | -.3809 | .2930 | -.6720 |
| 201 | 2.9997 | 46.0944 | 26.5700 | -90.0000 | .3549 | .4380 | .1173 | -.2330 | .5134 | -.5463 |
| 201 | 3.0425 | 46.4374 | 28.5700 | -90.0000 | .5872 | .4097 | .0380 | -.0790 | .7116 | -.3230 |
| 201 | 3.0012 | 46.1095 | 30.5700 | -90.0000 | .8456 | .4065 | -.0886 | .0801 | .9348 | .0724 |
| 201 | 2.9968 | 46.1086 | 32.5700 | -90.0000 | .8987 | .4402 | -.0866 | .1128 | .9944 | .1687 |
| 201 | 2.9971 | 46.1089 | 34.5700 | -90.0000 | .8100 | .4595 | -.0934 | .0812 | .9277 | .1728 |
| 201 | 2.9576 | 45.8504 | 40.5700 | -90.0000 | .7416 | .6013 | -.0936 | .0256 | .9543 | .1286 |
| 201 | 2.9188 | 45.5710 | 50.5700 | -90.0000 | .6156 | .7598 | -.1041 | -.0071 | .9778 | .0933 |
| 201 | 2.9085 | 45.5396 | 60.5700 | -90.0000 | .5154 | .9224 | -.1289 | -.0043 | 1.0566 | .1203 |
| 201 | 2.8993 | 45.4645 | 70.5700 | -90.0000 | .3685 | 1.0358 | -.1501 | .0029 | 1.0994 | .0394 |
| 201 | 2.9027 | 45.5445 | 80.5700 | -90.0000 | .2059 | 1.1190 | -.1837 | .0198 | 1.1276 | .0288 |
| 201 | 2.8811 | 45.3823 | 90.5700 | -90.0000 | .0114 | 1.1[illegible]41 | -.2[illegible]34 | .0225 | 1.1140 | .0979 |

TABLE VIII

BALANCED AILERONS    180 RPM    TRIP STRIPS ON    AILERON GAPS OPEN    VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 301 | 10.6944 | 88.1485 | .5700 | 0.0000 | .1676 | .0208 | -.0709 | -.0192 | .1678 | .0000 |
| 301 | 10.7208 | 88.1262 | 4.5700 | 0.0000 | .4692 | .0333 | -.0825 | .0042 | .4703 | .0000 |
| 301 | 10.7620 | 88.4739 | 8.5700 | 0.0000 | .7508 | .0564 | -.0841 | .0561 | .7508 | .0000 |
| 301 | 10.7994 | 89.5849 | 10.5700 | 0.0000 | .8596 | .0697 | -.0848 | [illegible]892 | .8578 | .0000 |
| 301 | 10.6775 | 88.0784 | 12.5700 | 0.0000 | .9727 | .0846 | -.0899 | .1292 | .9678 | .0000 |
| 301 | 10.6799 | 88.0988 | 14.5700 | 0.0000 | 1.0417 | .1027 | -.0953 | .1626 | 1.0340 | .0000 |
| 301 | 10.6846 | 88.1644 | 16.5700 | 0.0000 | 1.0899 | .1217 | -.1050 | .1942 | 1.0794 | .0000 |
| 301 | 10.6252 | 87.8284 | 18.5700 | 0.0000 | 1.1316 | .1486 | -.1040 | .2195 | 1.1200 | .0000 |
| 301 | 10.5818 | 87.7944 | 20.5700 | 0.0000 | 1.1390 | .1855 | -.1097 | .2266 | 1.1315 | .0000 |
| 301 | 10.7908 | 89.0939 | 22.5700 | 0.0000 | 1.0790 | .2395 | -.1258 | .1930 | 1.0883 | .0000 |
| 301 | 10.6158 | 88.2708 | 24.5700 | 0.0000 | 1.0482 | .2877 | -.1361 | .1742 | 1.0729 | .0000 |
| 301 | 10.4897 | 87.5089 | 26.5700 | 0.0000 | 1.0008 | .3283 | -.1475 | .1541 | 1.0420 | .0000 |
| 301 | 10.4404 | 87.1971 | 28.5700 | 0.0000 | .9676 | .3685 | -.1448 | .1391 | 1.0260 | .0000 |
| 301 | 10.1577 | 85.7651 | 32.5700 | 0.0000 | .9284 | .4772 | -.1609 | .0977 | 1.0393 | .0000 |
| 301 | 10.1373 | 85.5338 | 34.5700 | 0.0000 | .9031 | .5131 | -.1690 | .0899 | 1.0348 | .0000 |
| 301 | 9.9785 | 84.8213 | 36.5700 | 0.0000 | .8511 | .5907 | -.1717 | .0327 | 1.0355 | .0000 |
| 301 | [illegible].6862 | 83.3451 | 50.5700 | 0.0000 | .7847 | .9043 | -.2315 | .0317 | 1.1968 | .0000 |
| 301 | 9.5672 | 82.6521 | 60.5700 | 0.0000 | .6654 | 1.0656 | -.2633 | .0555 | 1.2560 | .0000 |
| 301 | [illegible].4531 | 82.1563 | 70.5700 | 0.0000 | .5050 | 1.2220 | -.3106 | .0697 | 1.3204 | .0000 |
| 301 | [illegible]2314 | 81.2756 | 90.5700 | 0.0000 | .1098 | 1.3341 | -.3786 | .1231 | 1.3330 | .0000 |
| 302 | [illegible]810 | 88.0755 | .5700 | -5.0000 | -.1074 | .0220 | -.0215 | -.0230 | -.1072 | .0708 |
| 302 | [illegible]08 | 88.3253 | 4.5700 | -5.0000 | .2087 | .0260 | -.0334 | -.0093 | .2101 | .1160 |
| 302 | [illegible]83 | 88.4322 | 8.5700 | -5.0000 | .5381 | .0406 | -.0401 | .0401 | .5362 | .1551 |
| 302 | [illegible]3 | 88.2854 | 12.5700 | -5.0000 | .8405 | .0685 | -.0557 | .1161 | .8353 | .2172 |
| 302 | [illegible]08 | 89.4807 | 16.5700 | -5.0000 | .9843 | .1080 | -.0812 | .1772 | .9742 | .2657 |
| 302 | [illegible]331 | 87.9894 | 20.5700 | -5.0000 | 1.0447 | .1553 | -.0807 | .2216 | 1.0327 | .2865 |
| 302 | 10.[illegible]363 | 88.3568 | 24.5700 | -5.0000 | .9711 | .2549 | -.1106 | .1720 | .9892 | .3405 |
| 302 | 10.[illegible]12 | 87.3724 | 28.5700 | -5.0000 | .9060 | .3301 | -.1152 | .1434 | .9535 | .3361 |
| 302 | 10.2554 | 86.1981 | 32.5700 | -5.0000 | .8685 | .4437 | -.1366 | .0936 | .9708 | .3585 |
| 302 | 10.0093 | 84.8740 | 36.5700 | -5.0000 | .8024 | .5467 | -.1520 | .0390 | .9702 | .3469 |
| 303 | 10.6521 | 87.9244 | .5700 | -10.0000 | -.1676 | .0645 | .0277 | -.0661 | -.1669 | -.0242 |
| 303 | 10.7242 | 88.1482 | 4.5700 | -10.0000 | .1035 | .0626 | .0209 | -.0541 | .1082 | .0263 |
| 303 | 10.8025 | 88.6219 | 8.5700 | -10.0000 | .3965 | .0648 | .0137 | -.0050 | .4017 | .0680 |
| 303 | 10.6878 | 88.0999 | 12.5700 | -10.0000 | .6591 | .0755 | .0110 | .0697 | .6597 | .1075 |
| 303 | 10.6685 | 88.0921 | 16.5700 | -10.0000 | .8116 | .1004 | .0035 | .1352 | .8065 | .1659 |
| 303 | 10.6293 | 87.9622 | 20.5700 | -10.0000 | .8549 | .1419 | -.0079 | .1675 | .8503 | .2389 |
| 303 | 10.6482 | 88.3481 | 24.5700 | -10.0000 | .8408 | .2246 | -.0423 | .1454 | .8581 | .3289 |
| 303 | 10.5044 | 87.4397 | 28.5700 | -10.0000 | .7675 | .2919 | -.0679 | .1107 | .8137 | .3361 |
| 303 | 10.3232 | 86.3364 | 32.5700 | -10.0000 | .7516 | .3971 | -.0890 | .0700 | .8472 | .3653 |
| 303 | 10.0332 | 84.9361 | 36.5700 | -10.0000 | .6870 | .5006 | -.1080 | .0073 | .8500 | .3621 |

TABLE VIII

BALANCED AILERONS 180 RPM TRIP STRIPS ON AILERON GAPS OPEN VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 304 | 10.6047 | 87.7403 | .5700 | -15.0000 | -.1120 | .0909 | .0351 | -.0920 | -.1110 | -.0594 |
| 304 | 10.6188 | 87.7004 | 4.5700 | -15.0000 | .1595 | .0866 | .0324 | -.0736 | .1659 | -.0149 |
| 304 | 10.7151 | 88.2513 | 8.5700 | -15.0000 | .4409 | .0923 | .0291 | -.0256 | .4497 | .0070 |
| 304 | 10.6598 | 88.0003 | 12.5700 | -15.0000 | .7117 | .1016 | .0221 | .0557 | .7167 | .0320 |
| 304 | 10.7028 | 88.2010 | 16.5700 | -15.0000 | .9094 | .1238 | .0136 | .1407 | .9069 | .0792 |
| 304 | 10.6609 | 88.0871 | 20.5700 | -15.0000 | .9766 | .1622 | -.0033 | .1912 | .9713 | .1165 |
| 304 | 10.7331 | 88.6501 | 24.5700 | -15.0000 | .6677 | .2152 | .0382 | .0820 | .6967 | .1579 |
| 304 | 10.5122 | 87.4513 | 28.5700 | -15.0000 | .5939 | .2714 | .0114 | .0456 | .6514 | .2007 |
| 304 | 10.2656 | 86.1600 | 32.5700 | -15.0000 | .5904 | .3656 | -.0180 | .0098 | .6944 | .2654 |
| 304 | 10.1339 | 85.3355 | 36.5700 | -15.0000 | .5913 | .4267 | -.0462 | .0096 | .7291 | .3081 |
| 305 | 10.6468 | 87.9089 | .5700 | -20.0000 | -.1566 | .1116 | .0492 | -.1131 | -.1555 | -.0759 |
| 305 | 10.5479 | 87.4170 | 4.5700 | -20.0000 | .1143 | .1100 | .0505 | -.1005 | .1227 | -.0486 |
| 305 | 10.7011 | 88.1807 | 8.5700 | -20.0000 | .3875 | .1104 | .0407 | -.0514 | .3997 | -.0095 |
| 305 | 10.6257 | 87.8712 | 12.5700 | -20.0000 | .6689 | .1166 | .0376 | .0318 | .6783 | .0059 |
| 305 | 10.7343 | 88.3481 | 16.5700 | -20.0000 | .8951 | .1384 | .0203 | .1226 | .8974 | .0572 |
| 305 | 10.6782 | 88.1250 | 20.5700 | -20.0000 | 1.0603 | .1764 | -.0113 | .2074 | 1.0547 | .1054 |
| 305 | 10.6281 | 88.2180 | 24.5700 | -20.0000 | .8468 | .2539 | .0060 | .1212 | .8757 | .1456 |
| 305 | 10.5557 | 87.6239 | 28.5700 | -20.0000 | .5745 | .2998 | .0315 | .0115 | .6480 | .0994 |
| 305 | 10.2963 | 86.3276 | 32.5700 | -20.0000 | .4630 | .3630 | .0440 | -.0567 | .5856 | .1056 |
| 305 | 10.0853 | 85.1206 | 36.5700 | -20.0000 | .4250 | .4350 | .0211 | -.0961 | .6005 | .1565 |
| 306 | 10.5279 | 87.4013 | .5700 | -25.0000 | -.2675 | .1489 | .0789 | -.1516 | -.2660 | -.1488 |
| 306 | 10.6006 | 87.5853 | 4.5700 | -25.0000 | .0193 | .1370 | .0662 | -.1351 | .0301 | -.0916 |
| 306 | 10.6180 | 87.8567 | 8.5700 | -25.0000 | .2833 | .1362 | .0626 | -.0925 | .3004 | -.0713 |
| 306 | 10.6170 | 87.7843 | 12.5700 | -25.0000 | .5709 | .1370 | .0587 | -.0094 | .5870 | -.0399 |
| 306 | 10.5690 | 87.6363 | 16.5700 | -25.0000 | .8404 | .1466 | .0431 | .0992 | .8473 | .0157 |
| 306 | 10.6926 | 88.1929 | 20.5700 | -25.0000 | 1.0674 | .1883 | -.0152 | .1987 | 1.0655 | .0760 |
| 306 | 10.6761 | 88.4371 | 24.5700 | -25.0000 | .9060 | .2738 | -.0250 | .1277 | .9378 | .1625 |
| 306 | 10.4269 | 86.9993 | 28.5700 | -25.0000 | .7142 | .3349 | -.0105 | .0475 | .7874 | .1289 |
| 306 | 10.1825 | 85.8006 | 32.5700 | -25.0000 | .6101 | .4034 | .0027 | -.0116 | .7313 | .1272 |
| 306 | 10.0649 | 85.0187 | 36.5700 | -25.0000 | .5331 | .4890 | -.0028 | -.0751 | .7195 | .1214 |
| 307 | 10.4868 | 87.2209 | .5700 | -30.0000 | -.3573 | .1870 | .1046 | -.1906 | -.3555 | -.1929 |
| 307 | 10.5062 | 87.2131 | 4.5700 | -30.0000 | -.0903 | .1732 | .0936 | -.1799 | -.0762 | -.1480 |
| 307 | 10.6376 | 87.9243 | 8.5700 | -30.0000 | .1718 | .1689 | .0911 | -.1415 | .1950 | -.1252 |
| 307 | 10.5925 | 87.7043 | 12.5700 | -30.0000 | .4565 | .1619 | .0786 | -.0587 | .4808 | -.0907 |
| 307 | 10.6565 | 88.0204 | 16.5700 | -30.0000 | .7218 | .1660 | .0701 | .0467 | .7392 | -.0365 |
| 307 | 10.6201 | 87.9573 | 20.5700 | -30.0000 | .9711 | .1963 | .0188 | .1574 | .9781 | .0071 |
| 307 | 10.6273 | 88.2257 | 24.5700 | -30.0000 | .9871 | .2738 | -.0360 | .1614 | 1.0115 | .1432 |
| 307 | 10.4176 | 87.0222 | 28.5700 | -30.0000 | .8049 | .3573 | -.0370 | .0711 | .8778 | .1640 |
| 307 | 10.2528 | 86.0551 | 32.5700 | -30.0000 | .6741 | .4455 | -.0256 | -.0126 | .8079 | .1414 |
| 307 | 10.0587 | 84.9495 | 36.5700 | -30.0000 | .5855 | .5372 | -.0337 | -.0826 | .7903 | .1535 |

TABLE VIII

BALANCED AILERONS    180 RPM    TRIP STRIPS ON    AILERON GAPS OPEN    VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 308 | 10.4112 | 86.9170 | .5700 | -35.0000 | -.4500 | .2239 | .1238 | -.2284 | -.4477 | -.2558 |
| 308 | 10.4464 | 86.9682 | 4.5700 | -35.0000 | -.1910 | .2080 | .1148 | -.2226 | -.1738 | -.2036 |
| 308 | 10.5570 | 87.5726 | 8.5700 | -35.0000 | .0683 | .1981 | .1111 | -.1858 | .0970 | -.1829 |
| 308 | 10.5842 | 87.7010 | 12.5700 | -35.0000 | .3507 | .1913 | .1029 | -.1104 | .3839 | -.1352 |
| 308 | 10.6723 | 88.0736 | 16.5700 | -35.0000 | .6006 | .1931 | .0987 | -.0138 | .6307 | -.0974 |
| 308 | 10.5914 | 87.7899 | 20.5700 | -35.0000 | .8681 | .2142 | .0501 | .1044 | .8881 | -.0248 |
| 308 | 10.5822 | 87.9917 | 24.5700 | -35.0000 | .9706 | .2849 | -.0281 | .1444 | 1.0012 | .1109 |
| 308 | 10.3944 | 86.8513 | 28.5700 | -35.0000 | .8766 | .3679 | -.0576 | .0961 | .9458 | .1828 |
| 308 | 10.2593 | 86.0651 | 32.5700 | -35.0000 | .7256 | .4596 | -.0404 | .0033 | .8589 | .1634 |
| 308 | 9.9809 | 84.5932 | 36.5700 | -35.0000 | .6538 | .5567 | -.0548 | -.0575 | .8568 | .1725 |
| 309 | 10.4135 | 86.8973 | .5700 | -40.0000 | -.5418 | .2550 | .1382 | -.2604 | -.5392 | -.2898 |
| 309 | 10.3870 | 86.7216 | 4.5700 | -40.0000 | -.3002 | .2451 | .1354 | -.2683 | -.2798 | -.2805 |
| 309 | 10.4951 | 87.3466 | 8.5700 | -40.0000 | -.0375 | .2308 | .1255 | -.2338 | -.0026 | -.2377 |
| 309 | 10.5614 | 87.5838 | 12.5700 | -40.0000 | .2378 | .2248 | .1239 | -.1677 | .2811 | -.2103 |
| 309 | 10.5665 | 87.6304 | 16.5700 | -40.0000 | .4915 | .2203 | .1182 | -.0710 | .5339 | -.1356 |
| 309 | 10.5688 | 87.6858 | 20.5700 | -40.0000 | .7975 | .2293 | .0664 | .0656 | .8272 | -.0870 |
| 309 | 10.5628 | 87.9180 | 24.5700 | -40.0000 | .9351 | .2909 | -.0250 | .1243 | .9714 | .0851 |
| 309 | 10.4154 | 86.9367 | 28.5700 | -40.0000 | .9162 | .3713 | -.0671 | .1121 | .9822 | .1838 |
| 309 | 10.2118 | 85.8902 | 32.5700 | -40.0000 | .7842 | .4762 | -.0658 | .0208 | .9172 | .1814 |
| 309 | 9.9950 | 84.5827 | 36.5700 | -40.0000 | .6832 | .5779 | -.0687 | -.0571 | .8930 | .1827 |
| 310 | 10.2480 | 86.0354 | 34.5700 | -60.0000 | .8547 | .4918 | -.1031 | .0800 | .9828 | .2111 |
| 310 | 9.8234 | 83.8546 | 50.5700 | -60.0000 | .5484 | .7795 | -.0973 | -.0715 | .9504 | .1435 |
| 310 | 9.6501 | 83.0147 | 60.5700 | -60.0000 | .4135 | .8959 | -.1061 | -.0800 | .9835 | .1175 |
| 310 | 9.6057 | 82.7953 | 70.5700 | -60.0000 | .2352 | .9616 | -.1172 | -.0981 | .9851 | .1417 |
| 310 | 9.6239 | 82.8377 | 90.5700 | -60.0000 | -.0929 | .9376 | -.1481 | -.0836 | .9385 | .2298 |
| 311 | 10.2652 | 86.0472 | 34.5700 | -70.0000 | .8672 | .4722 | -.1051 | .1033 | .9820 | .2036 |
| 311 | 9.7809 | 83.6742 | 50.5700 | -70.0000 | .6066 | .7867 | -.1132 | -.0312 | .9929 | .1422 |
| 311 | 9.6893 | 83.1855 | 60.5700 | -70.0000 | .4573 | .8940 | -.1232 | -.0410 | 1.0033 | .1365 |
| 311 | 9.6262 | 82.8827 | 70.5700 | -70.0000 | .2828 | .9777 | -.1340 | -.0586 | 1.0161 | .1298 |
| 311 | 9.4861 | 82.2529 | 90.5700 | -70.0000 | -.1024 | .9931 | -.1561 | -.0925 | .9940 | .1644 |
| 312 | 10.2437 | 85.9452 | 34.5700 | -80.0000 | .8631 | .4536 | -.0909 | .1162 | .9681 | .1348 |
| 312 | 9.8705 | 84.0507 | 50.5700 | -80.0000 | .6200 | .7594 | -.1129 | -.0034 | .9804 | .1445 |
| 312 | 9.6958 | 83.1630 | 60.5700 | -80.0000 | .4996 | .8933 | -.1304 | -.0038 | 1.0235 | .1253 |
| 312 | 9.6791 | 83.0530 | 70.5700 | -80.0000 | .3379 | .9795 | -.1505 | -.0071 | 1.0361 | .1158 |
| 312 | 9.5438 | 82.4824 | 90.5700 | -80.0000 | -.0326 | 1.0295 | -.1814 | -.0223 | 1.0297 | .1248 |
| 313 | 9.9710 | 85.0436 | .5700 | -90.0000 | -1.3906 | .4764 | .2243 | -.4902 | -1.3858 | -.7723 |
| 313 | 10.0979 | 85.4743 | 4.5700 | -90.0000 | -1.1839 | .4691 | .2213 | -.5619 | -1.1427 | -.7602 |
| 313 | 10.2254 | 85.1974 | 8.5700 | -90.0000 | -.9434 | .4719 | .2104 | -.6073 | -.8626 | -.7450 |
| 313 | 10.2024 | 86.0741 | 10.5700 | -90.0000 | -.8106 | .4703 | .2124 | -.6110 | -.7106 | -.7320 |
| 313 | 10.1917 | 86.0250 | 12.5700 | -90.0000 | -.6864 | .4610 | .2033 | -.5993 | -.5696 | -.7131 |

## TABLE VIII

BALANCED AILERONS    180 RPM    TRIP STRIPS ON    AILERON GAPS OPEN    VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 313 | 10.2808 | 86.4364 | 14.5700 | -90.0000 | -.5907 | .4728 | .1996 | -.6062 | -.4527 | -.7283 |
| 313 | 10.2594 | 85.3567 | 16.5700 | -90.0000 | -.4674 | .4626 | .1938 | -.5767 | -.3160 | -.6791 |
| 313 | 10.2622 | 85.3700 | 18.5700 | -90.0000 | -.3395 | .4555 | .1894 | -.5399 | -.1768 | -.6749 |
| 313 | 10.3290 | 85.6914 | 20.5700 | -90.0000 | -.2297 | .4628 | .1849 | -.5140 | -.0524 | -.6611 |
| 313 | 10.4719 | 87.7912 | 22.5700 | -90.0000 | -.0774 | .4433 | .1676 | -.4390 | .0987 | -.6171 |
| 313 | 10.4833 | 87.5716 | 24.5700 | -90.0000 | .0849 | .4330 | .1354 | -.3585 | .2572 | -.5342 |
| 313 | 10.4286 | 87.2234 | 26.5700 | -90.0000 | .3051 | .4174 | .0865 | -.2368 | .4596 | -.4066 |
| 313 | 10.3651 | 86.7395 | 28.5700 | -90.0000 | .4883 | .4084 | .0369 | -.1251 | .6242 | -.3009 |
| 313 | 10.2320 | 85.9166 | 32.5700 | -90.0000 | .7594 | .4274 | -.0464 | .0486 | .8700 | -.0233 |
| 313 | 10.2326 | 85.8305 | 34.5700 | -90.0000 | .8080 | .4424 | -.0748 | .0942 | .9164 | .0504 |
| 313 | 10.0096 | 84.6875 | 36.5700 | -90.0000 | .8095 | .4877 | -.0890 | .0906 | .9408 | .1392 |
| 313 | 9.8238 | 83.8375 | 50.5700 | -90.0000 | .6329 | .7456 | -.1128 | .0153 | .9779 | .1414 |
| 313 | 9.6579 | 82.9956 | 60.5700 | -90.0000 | .5214 | .8939 | -.1368 | .0149 | 1.0347 | .1010 |
| 313 | 9.5438 | 82.4651 | 70.5700 | -90.0000 | .3715 | .9920 | -.1564 | .0204 | 1.0591 | .1060 |
| 313 | 9.4781 | 82.2081 | 90.5700 | -90.0000 | .0265 | 1.0596 | -.1994 | .0370 | 1.0593 | .1022 |

TABLE IX

BALANCED AILERONS 100 RPM TRIP STRIPS OFF AILERON GAPS OPEN VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 301 | 3.1373 | 47.9856 | .5700 | -90.0000 | -1.3341 | .4602 | .2065 | -.4734 | -1.3295 | -.8461 |
| 301 | 3.0491 | 47.2779 | 4.5700 | -90.0000 | -1.1530 | .4652 | .2198 | -.5555 | -1.1122 | -.9026 |
| 301 | 3.0600 | 47.2573 | 8.5700 | -90.0000 | -.9400 | .4615 | .2053 | -.5964 | -.8608 | -.8951 |
| 301 | 3.0328 | 47.0872 | 10.5700 | -90.0000 | -.8066 | .4506 | .2033 | -.5909 | -.7103 | -.7834 |
| 301 | 3.0560 | 47.2314 | 12.5700 | -90.0000 | -.7225 | .4740 | .2239 | -.6199 | -.6020 | -.7840 |
| 301 | 3.0494 | 46.9094 | 14.5700 | -90.0000 | -.5740 | .4674 | .2191 | -.5968 | -.4380 | -.7703 |
| 301 | 3.0103 | 46.7661 | 16.5700 | -90.0000 | -.4717 | .4721 | .2125 | -.5870 | -.3175 | -.7714 |
| 301 | 3.0452 | 47.0109 | 18.5700 | -90.0000 | -.2996 | .4683 | .1890 | -.5394 | -.1349 | -.7752 |
| 301 | 3.0382 | 46.9216 | 20.5700 | -90.0000 | -.2047 | .4708 | .1898 | -.5127 | -.0262 | -.7341 |
| 301 | 3.0836 | 47.2736 | 22.5700 | -90.0000 | -.0720 | .4621 | .1701 | -.4544 | .1109 | -.7468 |
| 301 | 3.0778 | 47.1709 | 24.5700 | -90.0000 | .1572 | .4385 | .1403 | -.3334 | .3253 | -.6084 |
| 301 | 3.0599 | 47.0656 | 26.5700 | -90.0000 | .3513 | .4157 | .0809 | -.2147 | .5001 | -.4436 |
| 301 | 3.0606 | 47.0845 | 28.5700 | -90.0000 | .5429 | .4155 | .0300 | -.1053 | .6755 | -.3615 |
| 301 | 3.0561 | 47.0553 | 30.5700 | -90.0000 | .7467 | .4118 | -.0569 | .0252 | .8523 | -.0651 |
| 301 | 3.0466 | 47.0327 | 32.5700 | -90.0000 | .8195 | .4356 | -.0889 | .0741 | .9251 | .1370 |
| 301 | 3.0317 | 46.9125 | 34.5700 | -90.0000 | .8456 | .4602 | -.1045 | .1009 | .9574 | .1372 |
| 301 | 3.0398 | 47.0162 | 36.5700 | -90.0000 | .7945 | .5156 | -.0959 | .0593 | .9453 | .118[illegible] |
| 301 | 3.0535 | 47.2828 | 40.5700 | -90.0000 | .7406 | .5930 | -.0994 | .0312 | .9482 | .2021 |
| 301 | 3.0039 | 46.8633 | 50.5700 | -90.0000 | .6270 | .7645 | -.1128 | -.0013 | .9887 | .1371 |
| 301 | 2.9607 | 46.5165 | 60.5700 | -90.0000 | .5136 | .9165 | -.1361 | -.0030 | 1.0505 | .0988 |
| 301 | 2.9348 | 46.3398 | 70.5700 | -90.0000 | .3737 | 1.0275 | -.1670 | .0106 | 1.0933 | .0886 |
| 301 | 2.9299 | 46.3012 | 80.5700 | -90.0000 | .1979 | 1.0769 | -.1761 | .0188 | 1.0948 | .1052 |
| 301 | 2.9082 | 46.1252 | 90.5700 | -90.0000 | .0145 | 1.0976 | -.2036 | .0254 | 1.0974 | .0076 |

TABLE X

BALANCED AILERONS 180 RPM TRIP STRIPS ON AILERON GAPS OPEN VORTEX GENERATORS ON

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 401 | 10.8139 | 89.1929 | .5700 | 0.0000 | .0988 | .0226 | -.0659 | -.0216 | .0991 | .0000 |
| 401 | 10.6729 | 88.2702 | 4.5700 | 0.0000 | .4756 | .0353 | -.0846 | .0027 | .4769 | .0000 |
| 401 | 10.5520 | 87.6134 | 8.5700 | 0.0000 | .7932 | .0575 | -.0928 | .0614 | .7930 | .0000 |
| 401 | 10.5247 | 87.4623 | 10.5700 | 0.0000 | .9412 | .0713 | -.0952 | .1025 | .9383 | .0000 |
| 401 | 10.4521 | 86.9221 | 12.5700 | 0.0000 | 1.1059 | .0890 | -.1225 | .1538 | 1.0988 | .0000 |
| 401 | 10.3612 | 86.4185 | 14.5700 | 0.0000 | 1.2086 | .1064 | -.1231 | .2011 | 1.1965 | .0000 |
| 401 | 10.3430 | 86.2846 | 16.5700 | 0.0000 | 1.2768 | .1359 | -.1283 | .2339 | 1.2626 | .0000 |
| 401 | 10.2874 | 85.9286 | 18.5700 | 0.0000 | 1.3465 | .1585 | -.1271 | .2786 | 1.3269 | .0000 |
| 401 | 10.1116 | 85.1059 | 20.5700 | 0.0000 | 1.3393 | .2072 | -.1359 | .2766 | 1.3268 | .0000 |
| 401 | 10.0117 | 84.5762 | 22.5700 | 0.0000 | 1.2949 | .2511 | -.1441 | .2651 | 1.2921 | .0000 |
| 401 | 10.0056 | 84.5026 | 24.5700 | 0.0000 | 1.3086 | .2991 | -.1531 | .2721 | 1.3144 | .0000 |
| 401 | 9.9139 | 84.0447 | 26.5700 | 0.0000 | 1.2586 | .3453 | -.1594 | .2541 | 1.2802 | .0000 |
| 401 | 9.9164 | 84.0413 | 28.5700 | 0.0000 | 1.1053 | .4012 | -.1667 | .1763 | 1.1626 | .0000 |
| 401 | 9.7555 | 83.3361 | 30.5700 | 0.0000 | 1.1420 | .4455 | -.1762 | .1973 | 1.2099 | .0000 |
| 401 | 9.7507 | 83.3402 | 32.5700 | 0.0000 | .9778 | .4815 | -.1632 | .1206 | 1.0832 | .0000 |
| 401 | 9.6947 | 83.0181 | 34.5700 | 0.0000 | .8676 | .5438 | -.1676 | .0446 | 1.0230 | .0000 |
| 401 | 9.6776 | 83.0564 | 36.5700 | 0.0000 | .8582 | .5907 | -.1734 | .0369 | 1.0412 | .0000 |
| 401 | 9.5574 | 82.5453 | 40.5700 | 0.0000 | .8261 | .6665 | -.1843 | .0310 | 1.0610 | .0000 |
| 401 | 9.4561 | 82.1807 | 50.5700 | 0.0000 | .7635 | .8795 | -.2230 | .0311 | 1.1643 | .0000 |
| 401 | 9.3618 | 81.8624 | 60.5700 | 0.0000 | .6599 | 1.0650 | -.2625 | .0515 | 1.2518 | .0000 |
| 401 | 9.2626 | 81.4399 | 70.5700 | 0.0000 | .5117 | 1.2193 | -.3057 | .0770 | 1.3201 | .0000 |
| 401 | 9.1963 | 81.2239 | 80.5700 | 0.0000 | .3214 | 1.2998 | -.3334 | .1041 | 1.3349 | .0000 |
| 401 | 9.1187 | 80.9135 | 90.5700 | 0.0000 | .1129 | 1.3323 | -.3722 | .1261 | 1.3311 | .0000 |
| 402 | 10.6419 | 88.4447 | .5700 | -5.0000 | -.0997 | .0243 | -.0304 | -.0252 | -.0995 | .0880 |
| 402 | 10.6489 | 88.1021 | 4.5700 | -5.0000 | .2221 | .0293 | -.0426 | -.0115 | .2237 | .1324 |
| 402 | 10.5969 | 87.8144 | 8.5700 | -5.0000 | .5547 | .0439 | -.0497 | .0393 | .5551 | .1483 |
| 402 | 10.4487 | 86.8850 | 12.5700 | -5.0000 | .8827 | .0675 | -.0648 | .1262 | .8763 | .1886 |
| 402 | 10.3754 | 86.3405 | 16.5700 | -5.0000 | 1.1458 | .1092 | -.0929 | .2221 | 1.1293 | .2280 |
| 402 | 10.1739 | 85.3388 | 20.5700 | -5.0000 | 1.2489 | .1775 | -.1051 | .2726 | 1.2316 | .2590 |
| 402 | 10.0147 | 84.5104 | 24.5700 | -5.0000 | 1.2285 | .2612 | -.1218 | .2733 | 1.2258 | .3067 |
| 403 | 10.5980 | 88.2813 | .5700 | -10.0000 | -.1915 | .0680 | .0267 | -.0699 | -.1908 | -.0173 |
| 403 | 10.6252 | 88.0316 | 4.5700 | -10.0000 | .1074 | .0679 | .0227 | -.0592 | .1124 | .0188 |
| 403 | 10.5103 | 87.4340 | 8.5700 | -10.0000 | .3864 | .0703 | .0127 | -.0119 | .3925 | .0492 |
| 403 | 10.4550 | 86.8996 | 12.5700 | -10.0000 | .6731 | .0769 | .0111 | .0715 | .6737 | .1026 |
| 403 | 10.4230 | 86.5654 | 16.5700 | -10.0000 | .9151 | .1023 | -.0163 | .1629 | .9063 | .1343 |
| 403 | 10.2414 | 85.6093 | 20.5700 | -10.0000 | 1.0584 | .1486 | -.0344 | .2327 | 1.0431 | .1968 |
| 403 | 10.0762 | 84.7522 | 24.5700 | -10.0000 | 1.0676 | .2306 | -.0620 | .2342 | 1.0668 | .2709 |
| 404 | 10.5797 | 88.1710 | .5700 | -15.0000 | -.1326 | .0967 | .0366 | -.0980 | -.1316 | -.0646 |
| 404 | 10.5308 | 87.6748 | 4.5700 | -15.0000 | .1589 | .0913 | .0307 | -.0783 | .1657 | -.0130 |
| 404 | 10.4973 | 87.3623 | 8.5700 | -15.0000 | .4397 | .0941 | .0248 | -.0276 | .4489 | .0116 |

TABLE X

BALANCED AILERONS 180 RPM TRIP STRIPS ON AILERON GAPS OPEN VORTEX GENERATORS ON

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 404 | 10.3975 | 86.6576 | 12.5700 | -15.0000 | .7048 | .1040 | .0241 | .0519 | .7105 | .0324 |
| 404 | 10.3286 | 86.1300 | 16.5700 | -15.0000 | .9404 | .1229 | .0017 | .1504 | .9364 | .0477 |
| 404 | 10.1587 | 85.2688 | 20.5700 | -15.0000 | 1.0401 | .1604 | -.0034 | .2153 | 1.0302 | .0795 |
| 404 | 10.1309 | 84.9711 | 24.5700 | -15.0000 | .9469 | .2259 | .0035 | .1883 | .9551 | .1124 |
| 405 | 10.4745 | 87.7352 | .5700 | -20.0000 | -.1845 | .1197 | .0525 | -.1216 | -.1833 | -.0935 |
| 405 | 10.5643 | 87.8042 | 4.5700 | -20.0000 | .1023 | .1120 | .0437 | -.1035 | .1109 | -.0373 |
| 405 | 10.4950 | 87.3471 | 8.5700 | -20.0000 | .3818 | .1138 | .0400 | -.0556 | .3945 | -.0305 |
| 405 | 10.4175 | 86.7040 | 12.5700 | -20.0000 | .6541 | .1207 | .0370 | .0245 | .6646 | .0087 |
| 405 | 10.3315 | 86.0949 | 16.5700 | -20.0000 | .9058 | .1376 | .0113 | .1264 | .9074 | .0279 |
| 405 | 10.1231 | 85.0900 | 20.5700 | -20.0000 | 1.0682 | .1855 | -.0144 | .2017 | 1.0653 | .0786 |
| 405 | 10.0998 | 84.8550 | 24.5700 | -20.0000 | .9924 | .2460 | -.0010 | .1889 | 1.0048 | .0941 |
| 413 | 9.9071 | 85.2786 | .5700 | -90.0000 | -1.3950 | .4866 | .2290 | -.5004 | -1.3901 | -.7645 |
| 413 | 9.9633 | 85.2604 | 4.5700 | -90.0000 | -1.1591 | .4685 | .2219 | -.5594 | -1.1181 | -.7506 |
| 413 | 10.0376 | 85.4225 | 8.5700 | -90.0000 | -.9480 | .4702 | .2150 | -.6062 | -.8674 | -.7500 |
| 413 | 9.9665 | 85.0731 | 10.5700 | -90.0000 | -.8147 | .4715 | .2111 | -.6130 | -.7144 | -.7394 |
| 413 | 9.9231 | 84.6185 | 12.5700 | -90.0000 | -.7066 | .4687 | .2091 | -.6112 | -.5877 | -.7254 |
| 413 | 9.9917 | 84.7961 | 14.5700 | -90.0000 | -.5994 | .4742 | .2060 | -.6097 | -.4608 | -.7137 |
| 413 | 9.9677 | 84.5821 | 16.5700 | -90.0000 | -.4930 | .4720 | .1994 | -.5930 | -.3379 | -.7059 |
| 413 | 9.9120 | 84.3185 | 18.5700 | -90.0000 | -.3469 | .4701 | .2002 | -.5560 | -.1791 | -.6872 |
| 413 | 9.8309 | 83.8316 | 20.5700 | -90.0000 | -.2380 | .4758 | .1964 | -.5291 | -.0556 | -.6655 |
| 413 | 9.9144 | 84.1246 | 22.5700 | -90.0000 | -.0940 | .4715 | .1839 | -.4715 | .0941 | -.6462 |
| 413 | 9.8244 | 83.7009 | 24.5700 | -90.0000 | .0527 | .4756 | .1700 | -.4106 | .2457 | -.6020 |
| 413 | 9.9071 | 83.8987 | 26.5700 | -90.0000 | .2662 | .4456 | .1290 | -.2795 | .4374 | -.4902 |
| 413 | 9.8883 | 83.8764 | 28.5700 | -90.0000 | .4717 | .4250 | .0746 | -.1477 | .6175 | -.3612 |
| 413 | 9.7675 | 83.3308 | 30.5700 | -90.0000 | .6527 | .4284 | .0184 | -.0369 | .7798 | -.2008 |
| 413 | 9.7058 | 83.0927 | 32.5700 | -90.0000 | .7903 | .4371 | -.0427 | .0571 | .9013 | -.0200 |
| 413 | 9.8117 | 83.5139 | 34.5700 | -90.0000 | .8067 | .4527 | -.0758 | .0850 | .9211 | .0758 |
| 413 | 9.7645 | 83.3725 | 36.5700 | -90.0000 | .8161 | .4867 | -.0900 | .0954 | .9454 | .1189 |
| 413 | 9.7087 | 83.1680 | 40.5700 | -90.0000 | .7699 | .5834 | -.1013 | .0575 | .9642 | .1362 |
| 413 | 9.5157 | 82.4126 | 50.5700 | -90.0000 | .6347 | .7547 | -.1175 | .0109 | .9860 | .1157 |
| 413 | 9.5578 | 82.6900 | 60.5700 | -90.0000 | .5136 | .8867 | -.1363 | .0116 | 1.0247 | .1507 |
| 413 | 9.4900 | 82.3867 | 70.5700 | -90.0000 | .3640 | .9765 | -.1520 | .0184 | 1.0420 | .0911 |
| 413 | 9.3443 | 81.8192 | 80.5700 | -90.0000 | .2051 | 1.0374 | -.1655 | .0323 | 1.0570 | .0825 |
| 413 | 9.3300 | 81.8226 | 90.5700 | -90.0000 | .0222 | 1.0692 | -.1909 | .0328 | 1.0689 | .1072 |

TABLE XI

BALANCED AILERONS 180 RPM TRIP STRIPS OFF AILERON GAPS OPEN VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 501 | 10.7591 | 89.2358 | .5700 | 0.0000 | .1538 | .0191 | -.0741 | -.0176 | .1539 | .0000 |
| 501 | 10.7082 | 89.5963 | 4.5700 | 0.0000 | .4793 | .0268 | -.0785 | .0114 | .4799 | .0000 |
| 501 | 10.5981 | 88.3884 | 8.5700 | 0.0000 | .7870 | .0530 | -.0864 | .0648 | .7861 | .0000 |
| 501 | 10.5927 | 88.1445 | 10.5700 | 0.0000 | .9107 | .0654 | -.0923 | .1028 | .9072 | .0000 |
| 501 | 10.5507 | 87.9705 | 12.5700 | 0.0000 | .9967 | .0817 | -.1082 | .1372 | .9906 | .0000 |
| 501 | 10.4712 | 87.1874 | 14.5700 | 0.0000 | 1.0602 | .0973 | -.0999 | .1726 | 1.0506 | .0000 |
| 501 | 10.4074 | 87.1379 | 16.5700 | 0.0000 | 1.1042 | .1145 | -.0976 | .2052 | 1.0910 | .0000 |
| 501 | 10.4414 | 87.2366 | 18.5700 | 0.0000 | 1.1232 | .1413 | -.1002 | .2237 | 1.1097 | .0000 |
| 501 | 10.2888 | 86.5483 | 20.5700 | 0.0000 | 1.1277 | .1738 | -.1015 | .2335 | 1.1169 | .0000 |
| 501 | 10.2200 | 86.2324 | 22.5700 | 0.0000 | 1.0854 | .2384 | -.1219 | .1964 | 1.0938 | .0000 |
| 501 | 10.2227 | 86.1800 | 24.5700 | 0.0000 | 1.0552 | .2834 | -.1404 | .1810 | 1.0775 | .0000 |
| 501 | 10.1413 | 85.8603 | 26.5700 | 0.0000 | 1.0069 | .3232 | -.1412 | .1613 | 1.0451 | .0000 |
| 501 | 10.0613 | 85.5631 | 28.5700 | 0.0000 | .9841 | .3646 | -.1386 | .1504 | 1.0386 | .0000 |
| 501 | 9.9946 | 85.2851 | 30.5700 | 0.0000 | .9556 | .4205 | -.1483 | .1240 | 1.0367 | .0000 |
| 501 | 10.0070 | 85.3327 | 32.5700 | 0.0000 | .9253 | .4751 | -.1567 | .0977 | 1.0355 | .0000 |
| 501 | 9.9340 | 85.0880 | 34.5700 | 0.0000 | .8963 | .5078 | -.1572 | .0905 | 1.0262 | .0000 |
| 501 | 9.9111 | 85.0136 | 36.5700 | 0.0000 | .8470 | .5786 | -.1673 | .0400 | 1.0250 | .0000 |
| 501 | 9.7752 | 84.7528 | 40.5700 | 0.0000 | .8335 | .6604 | -.1889 | .0404 | 1.0626 | .0000 |
| 501 | 9.7210 | 84.4953 | 50.5700 | 0.0000 | .7725 | .8856 | -.2285 | .0342 | 1.1747 | .0000 |
| 501 | 9.5740 | 83.7988 | 60.5700 | 0.0000 | .6713 | 1.0808 | -.2705 | .0536 | 1.2712 | .0000 |
| 501 | 9.4782 | 83.3999 | 70.5700 | 0.0000 | .5140 | 1.2233 | -.3110 | .0778 | 1.3246 | .0000 |
| 501 | 9.4612 | 83.4042 | 80.5700 | 0.0000 | .3245 | 1.2995 | -.3370 | .1072 | 1.3351 | .0000 |
| 501 | 9.3351 | 82.8145 | 90.5700 | 0.0000 | .1124 | 1.3512 | -.3739 | .1258 | 1.3500 | .0000 |
| 502 | 10.7551 | 89.1593 | .5700 | -5.0000 | -.1208 | .0216 | -.0205 | -.0228 | -.1205 | .0801 |
| 502 | 10.6994 | 88.6823 | 4.5700 | -5.0000 | .2152 | .0238 | -.0313 | -.0066 | .2164 | .1144 |
| 502 | 10.6537 | 88.5759 | 8.5700 | -5.0000 | .5601 | .0386 | -.0433 | .0453 | .5596 | .1484 |
| 502 | 10.4558 | 87.5419 | 12.5700 | -5.0000 | .8402 | .0648 | -.0551 | .1196 | .8341 | .2112 |
| 502 | 10.4731 | 87.4161 | 16.5700 | -5.0000 | .9947 | .1032 | -.0776 | .1848 | .9829 | .2576 |
| 502 | 10.3424 | 86.7521 | 20.5700 | -5.0000 | 1.0479 | .1505 | -.0780 | .2272 | 1.0339 | .3027 |
| 502 | 10.2392 | 86.2301 | 24.5700 | -5.0000 | .9685 | .2527 | -.1108 | .1729 | .9859 | .3400 |
| 503 | 10.6791 | 88.7910 | .5700 | -10.0000 | -.1503 | .0695 | .0313 | -.0710 | -.1496 | -.0289 |
| 503 | 10.6606 | 88.5441 | 4.5700 | -10.0000 | .1360 | .0630 | .0267 | -.0520 | .1406 | .0096 |
| 503 | 10.6060 | 88.1669 | 8.5700 | -10.0000 | .4003 | .0667 | .0185 | -.0063 | .4058 | .0372 |
| 503 | 10.5634 | 88.0157 | 12.5700 | -10.0000 | .6699 | .0746 | .0121 | .0729 | .6701 | .1074 |
| 503 | 10.4839 | 87.4552 | 16.5700 | -10.0000 | .8463 | .0948 | -.0008 | .1505 | .8382 | .1758 |
| 503 | 10.3061 | 86.5533 | 20.5700 | -10.0000 | .8748 | .1360 | -.0033 | .1800 | .8668 | .2521 |
| 503 | 10.2811 | 86.4044 | 24.5700 | -10.0000 | .8143 | .2175 | -.0359 | .1407 | .8310 | .3162 |
| 504 | 10.6465 | 89.5746 | .5700 | -15.0000 | -.1148 | .0932 | .0357 | -.0944 | -.1139 | -.0575 |
| 504 | 10.5376 | 89.0007 | 4.5700 | -15.0000 | .1628 | .0913 | .0419 | -.0780 | .1695 | -.0288 |
| 504 | 10.5983 | 88.1213 | 8.5700 | -15.0000 | .4344 | .0893 | .0318 | -.0236 | .4429 | -.0052 |

TABLE XI

BALANCED AILERONS 180 RPM TRIP STRIPS OFF AILERON GAPS OPEN VORTEX GENERATORS OFF

| RUN | T Q,PSF | T VEL,FPS | ALPHA | AIL DEF | CL | CD | CM | CC | CN | CAM |
|---|---|---|---|---|---|---|---|---|---|---|
| 504 | 10.4845 | 87.6386 | 12.5700 | -15.0000 | .7188 | .0992 | .0241 | .0596 | .7231 | .0487 |
| 504 | 10.4208 | 87.1253 | 16.5700 | -15.0000 | .9441 | .1185 | .0095 | .1557 | .9387 | .0845 |
| 504 | 10.3732 | 86.8476 | 20.5700 | -15.0000 | .9364 | .1519 | .0179 | .1868 | .9300 | .1316 |
| 504 | 10.2819 | 86.3689 | 24.5700 | -15.0000 | .6964 | .2175 | .0309 | .0918 | .7238 | .1635 |
| 505 | 10.6720 | 88.7105 | .5700 | -20.0000 | -.1617 | .1153 | .0505 | -.1170 | -.1605 | -.0918 |
| 505 | 10.5888 | 88.1630 | 4.5700 | -20.0000 | .1153 | .1117 | .0534 | -.1021 | .1238 | -.0633 |
| 505 | 10.5492 | 87.8902 | 8.5700 | -20.0000 | .3977 | .1111 | .0434 | -.0505 | .4098 | -.0392 |
| 505 | 10.4638 | 87.5319 | 12.5700 | -20.0000 | .6516 | .1143 | .0406 | .0302 | .6609 | .0240 |
| 505 | 10.3795 | 86.9702 | 16.5700 | -20.0000 | .9222 | .1285 | .0193 | .1398 | .9206 | .0604 |
| 505 | 10.3272 | 86.6153 | 20.5700 | -20.0000 | 1.0545 | .1757 | -.0119 | .2060 | 1.0490 | .1203 |
| 505 | 10.2987 | 86.4534 | 24.5700 | -20.0000 | .8368 | .2534 | .0009 | .1175 | .8664 | .1491 |
| 513 | 10.1334 | 86.4068 | .5700 | -90.0000 | -1.3802 | .4745 | .2233 | -.4882 | -1.3754 | -.7769 |
| 513 | 10.0419 | 85.9143 | 4.5700 | -90.0000 | -1.1720 | .4688 | .2288 | -.5607 | -1.1309 | -.7777 |
| 513 | 9.9728 | 5.4123 | 8.5700 | -90.0000 | -.8030 | .4332 | .1941 | -.5480 | -.7295 | -.6930 |
| 513 | 10.0221 | 85.7095 | 10.5700 | -90.0000 | -.8137 | .4725 | .2049 | -.6138 | -.7133 | -.7306 |
| 513 | 9.9505 | 85.3452 | 12.5700 | -90.0000 | -.7010 | .4716 | .2109 | -.6129 | -.5816 | -.7115 |
| 513 | 10.1352 | 85.6567 | 14.5700 | -90.0000 | -.5967 | .4718 | .2069 | -.6068 | -.4588 | -.6863 |
| 513 | 9.9792 | 85.2577 | 16.5700 | -90.0000 | -.4698 | .4698 | .2040 | -.5842 | -.3163 | -.6948 |
| 513 | 10.0397 | 85.4954 | 18.5700 | -90.0000 | -.3577 | .4721 | .1936 | -.5614 | -.1888 | -.6949 |
| 513 | 10.0373 | 85.4099 | 20.5700 | -90.0000 | -.2194 | .4632 | .1874 | -.5107 | -.0427 | -.6509 |
| 513 | 10.0360 | 85.4052 | 22.5700 | -90.0000 | -.1011 | .4578 | .1764 | -.4615 | .0824 | -.6427 |
| 513 | 10.0631 | 85.4475 | 24.5700 | -90.0000 | .0895 | .4385 | .1484 | -.3615 | .2637 | -.5499 |
| 513 | 10.0739 | 85.5670 | 26.5700 | -90.0000 | .3131 | .4202 | .0916 | -.2358 | .4680 | -.4121 |
| 513 | 10.0775 | 85.5907 | 28.5700 | -90.0000 | .4852 | .4064 | .0398 | -.1248 | .6205 | -.3050 |
| 513 | 10.0851 | 85.6644 | 30.5700 | -90.0000 | .6525 | .4099 | -.0050 | -.0210 | .7703 | -.1718 |
| 513 | 10.0191 | 85.4035 | 32.5700 | -90.0000 | .7736 | .4210 | -.0510 | .0617 | .8786 | -.0002 |
| 513 | 10.0418 | 85.4766 | 34.5700 | -90.0000 | .7922 | .4381 | -.0655 | .0887 | .9009 | .0499 |
| 513 | 10.0164 | 85.4612 | 36.5700 | -90.0000 | .8117 | .4823 | -.0912 | .0963 | .9392 | .1235 |
| 513 | 9.9923 | 85.6586 | 40.5700 | -90.0000 | .7783 | .5771 | -.1063 | .0679 | .9666 | .1595 |
| 513 | 9.8750 | 85.1541 | 50.5700 | -90.0000 | .6370 | .7512 | -.1183 | .0149 | .9848 | .1285 |
| 513 | 9.7279 | 84.4606 | 60.5700 | -90.0000 | .5303 | .9051 | -.1409 | .0172 | 1.0489 | .1192 |
| 513 | 9.6934 | 84.3236 | 70.5700 | -90.0000 | .3795 | 1.0009 | -.1598 | .0250 | 1.0701 | .1123 |
| 513 | 9.6478 | 84.1777 | 80.5700 | -90.0000 | .2098 | 1.0447 | -.1753 | .0358 | 1.0650 | .1106 |
| 513 | 9.5786 | 83.8894 | 90.5700 | -90.0000 | .0248 | 1.0652 | -.1956 | .0354 | 1.0649 | .0808 |

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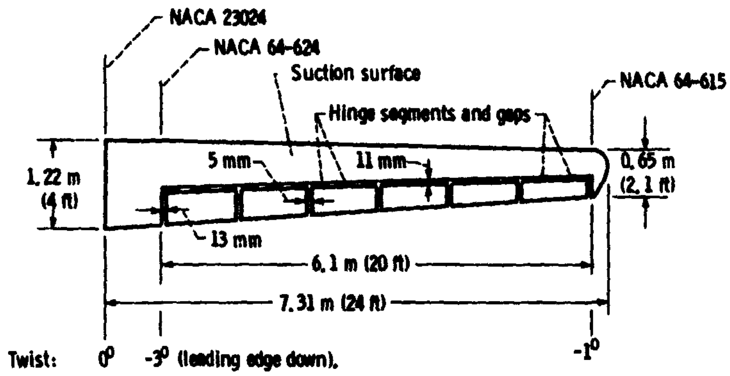
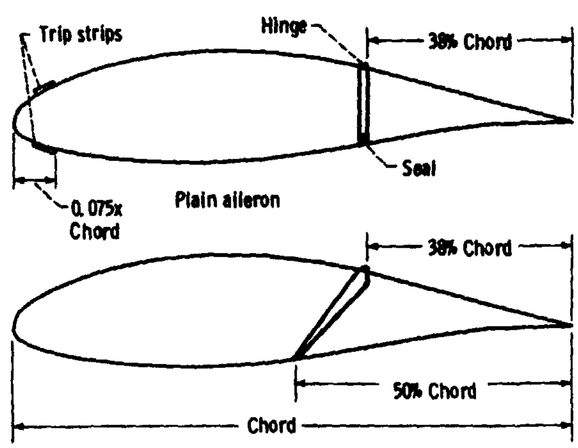
Figure 1. - DOE/NASA Mod-0 experimental wind turbine Plum Brook Station, Sandusky, Ohio.




(a) Plan form (looking at suction surface).




(b) Aileron configurations

Figure 2. - Description of the blade tip section.

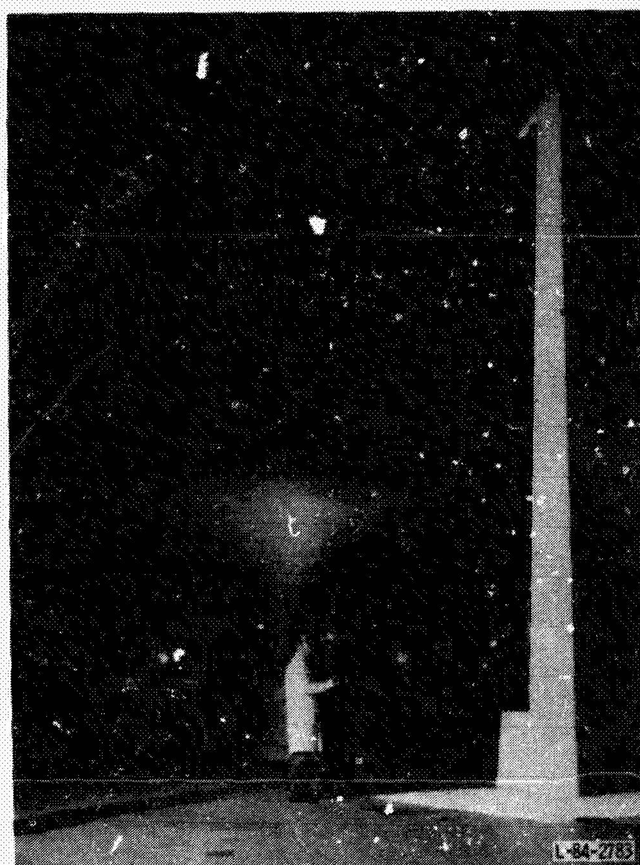



Figure 3. - View (from upstream) of the blade tip section mounted in the test section of the NASA Langley full scale wind tunnel. (Shown in the background are the tunnel fans.)

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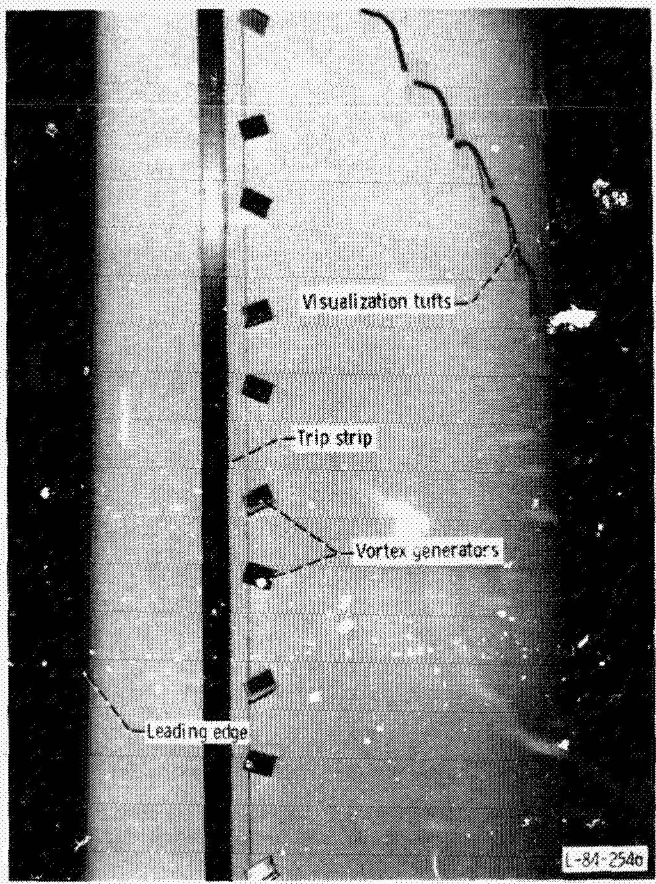
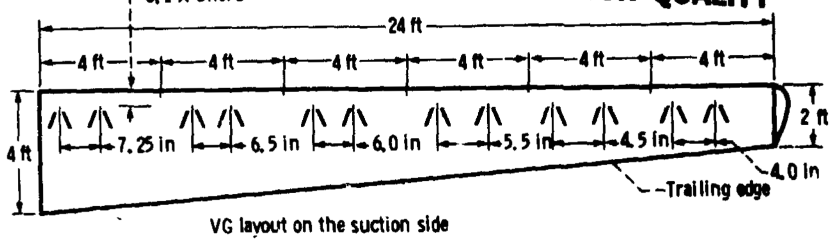
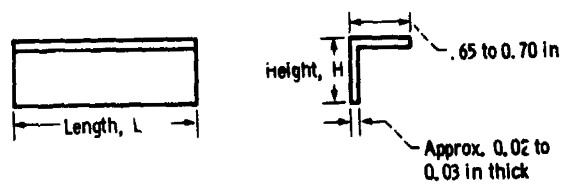



(a) Close-up view of vortex generators, trip strip, and visualization tufts.

Figure 4. - Vortex generators on the suction surface of the blade section.



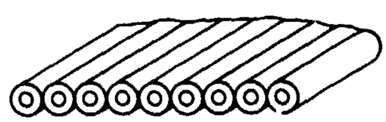

VG layout on the suction side



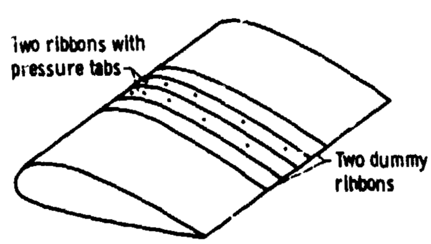

| Chord, in | Length, L in | Height, H in |
|---|---|---|
| 48 | 1.20 | 0.30 |
| 44 | 1.10 | 0.26 |
| 36 | 0.90 | 0.23 |
| 30 | 0.75 | 0.19 |
| 24 | 0.60 | 0.15 |

(b) Vortex generator dimensions & layout.

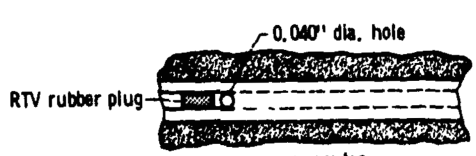
Figure 4. - Concluded.



Strip-a-tube molded ribbon
10-0.125 "ODx0.040" ID tubes



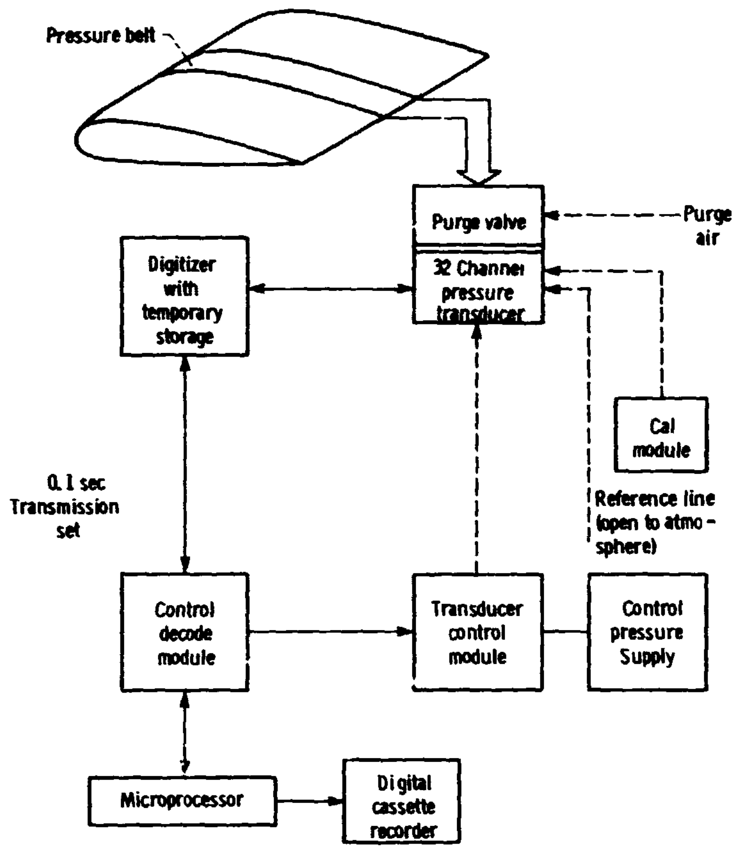

Pressure belt consisting of 4 "strip-a-tube" ribbons




pressure tap

(a) Pressure taps and tubing

Figure 5. - System for measuring blade surface pressures.




(b) block diagram

Figure 5. - Concluded.

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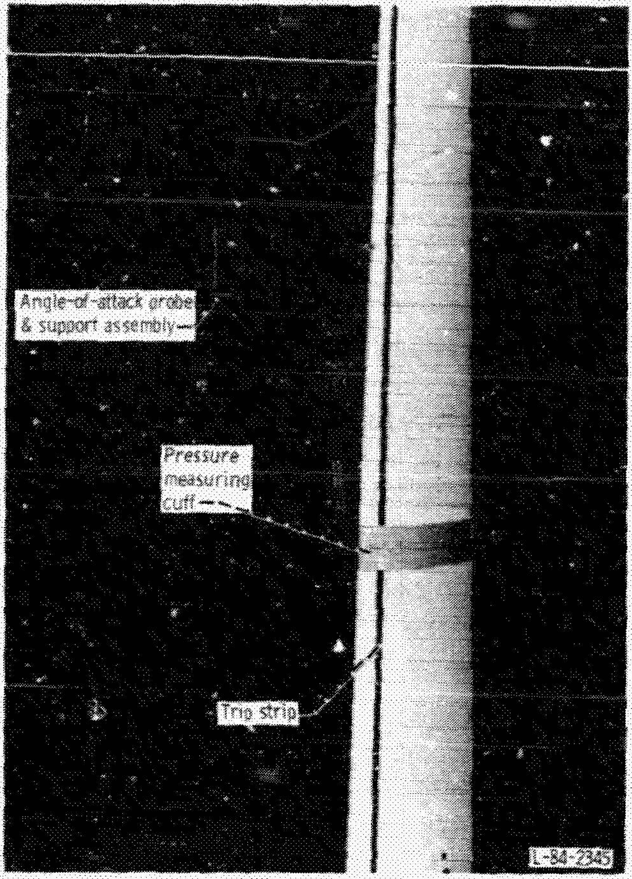



Figure 6. - View showing the pressure cuff, angle-of-attack probe, and the leading edge trip strip on the suction side.

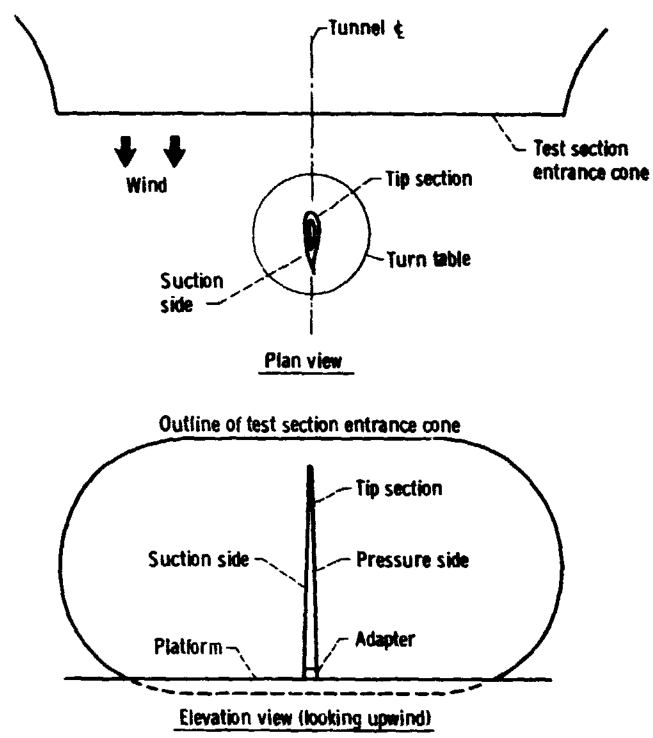



Figure 7. - Test setup in the Langley 30x60 foot wind tunnel.

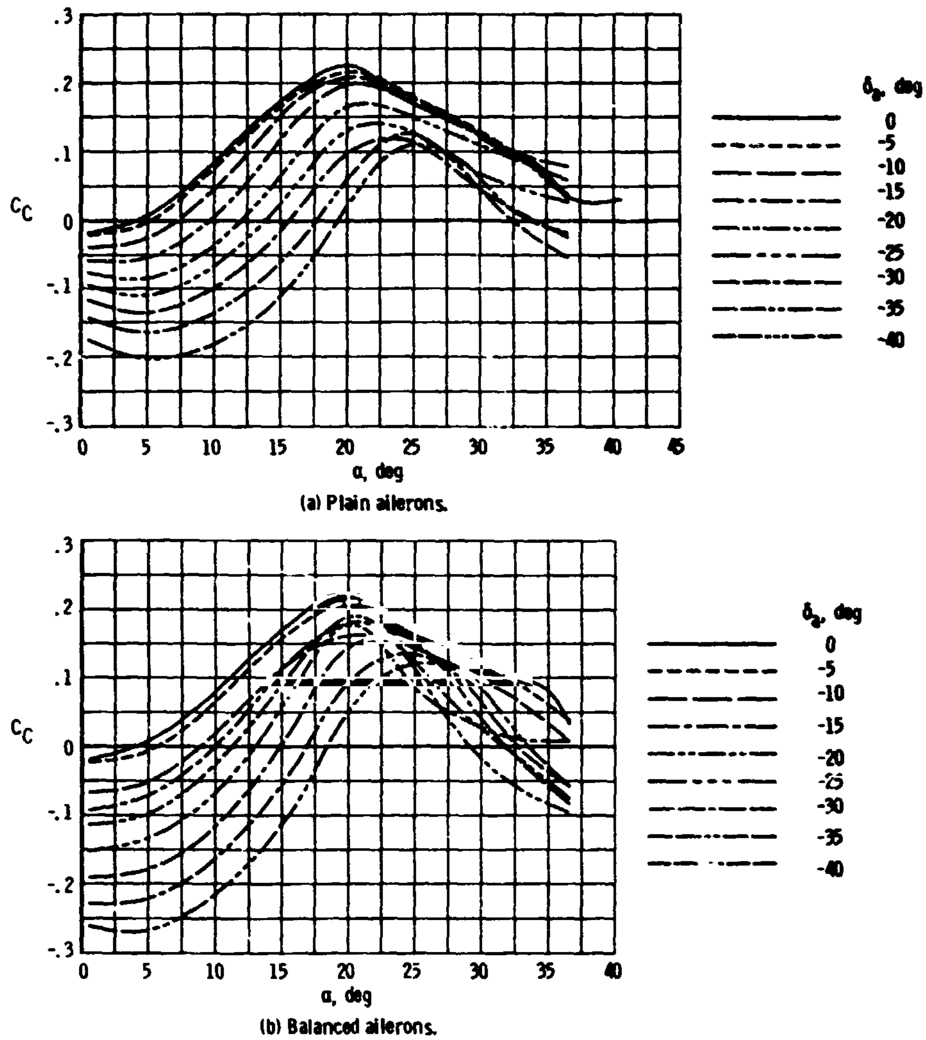



Figure 8. - Chordwise force coefficients for the blade tip section with plain and balanced ailerons.

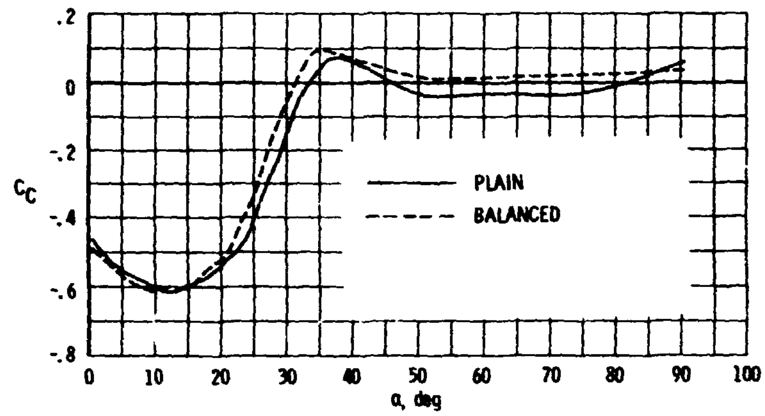
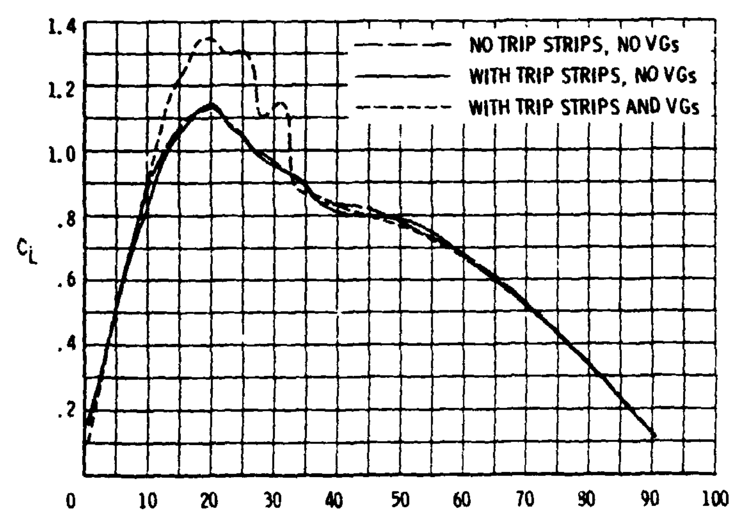
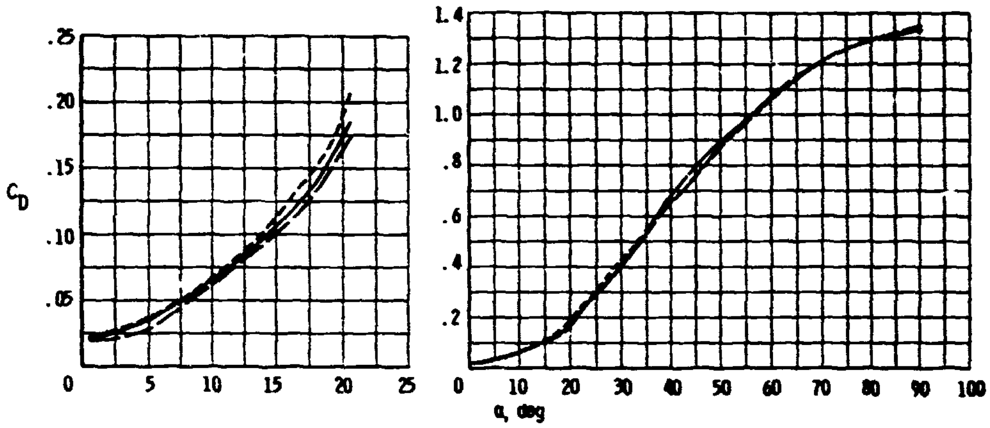



Figure 9. - Chordwise force coefficient for the blade tip section when the ailerons are deflected to -90°. Midspan Reynolds No. = $1.5\times10^6$ trip strips on the leading edge.

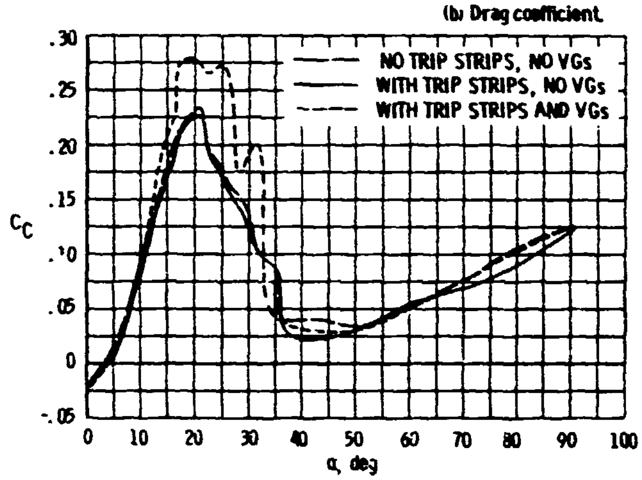



(a) Lift coefficient.

Figure 10. - The effect of trip strips, and vortex generators on the aerodynamic properties of the blade tip section with a balanced aileron at a zero deflection angle. Midspan Reynolds No. = $1.5\times10^6$.

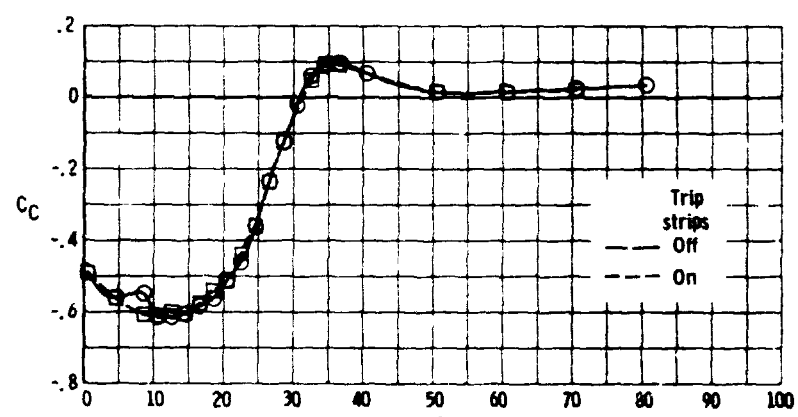



(b) Drag coefficient.



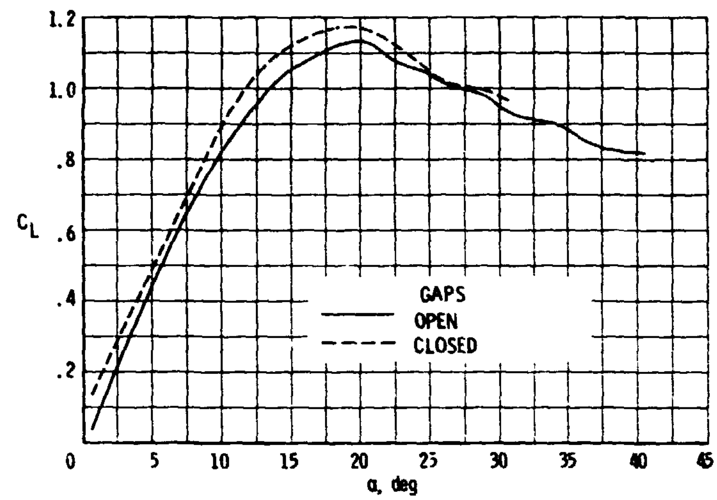

(c) Chordwise force coefficient.

Figure 10. - Continued.

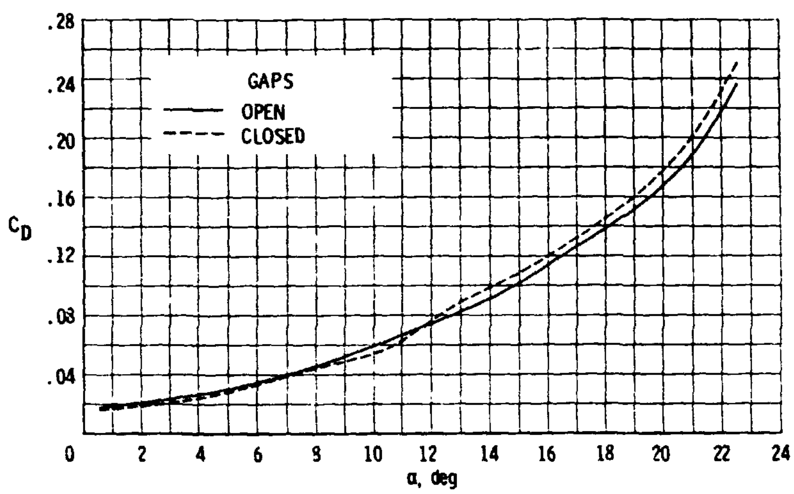



(d) Chordwise force coefficient, balance aileron deflection = $-90^0$.

Figure 10. - Concluded.

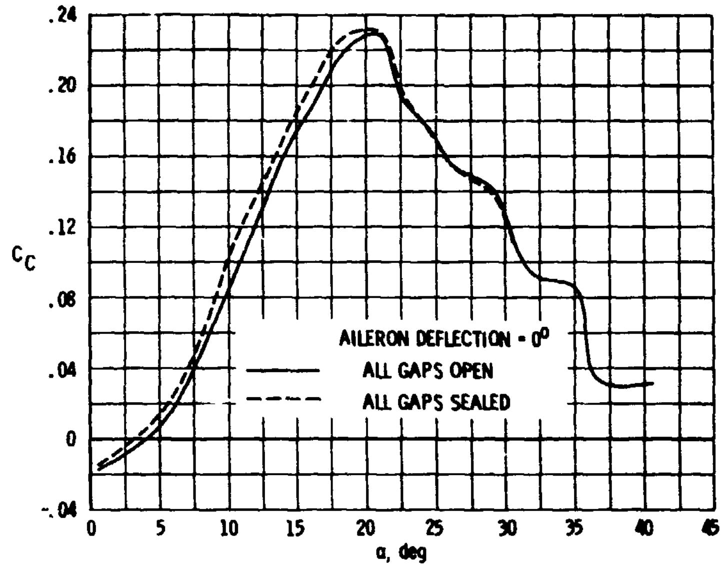



(a) Lift coefficient.



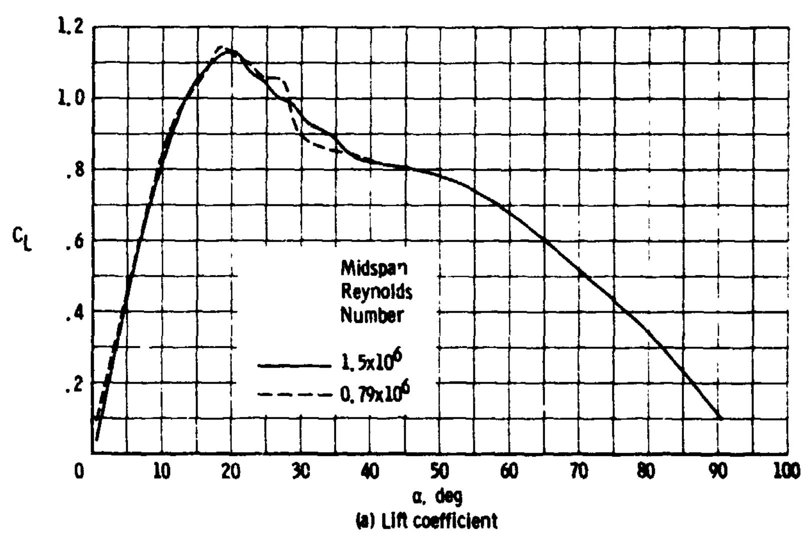

(b) Drag coefficient.

Figure 11. - Effect of various aileron gaps on the blade tip aerodynamics, midspan Reynolds number = 1.5 million, plain aileron, trip strips on the leading edge, aileron deflection=0°.



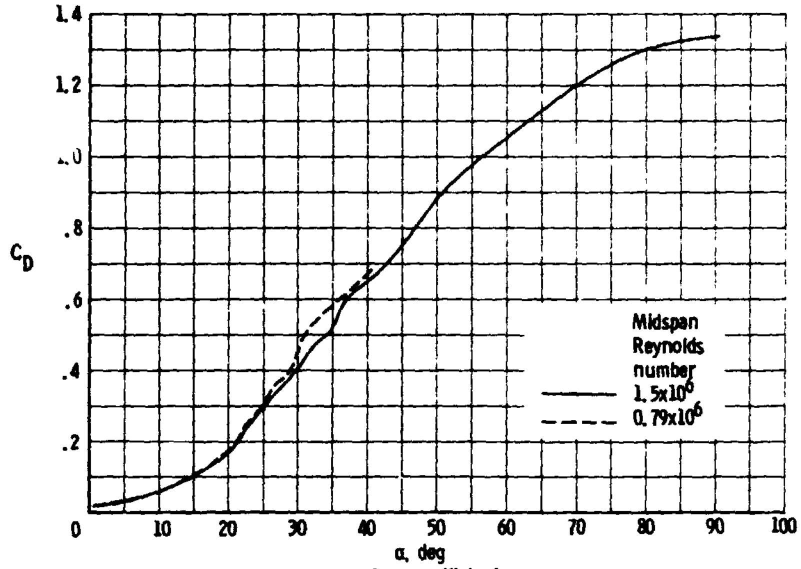

(c) Chordwise force coefficient.

Figure 11. - Concluded.



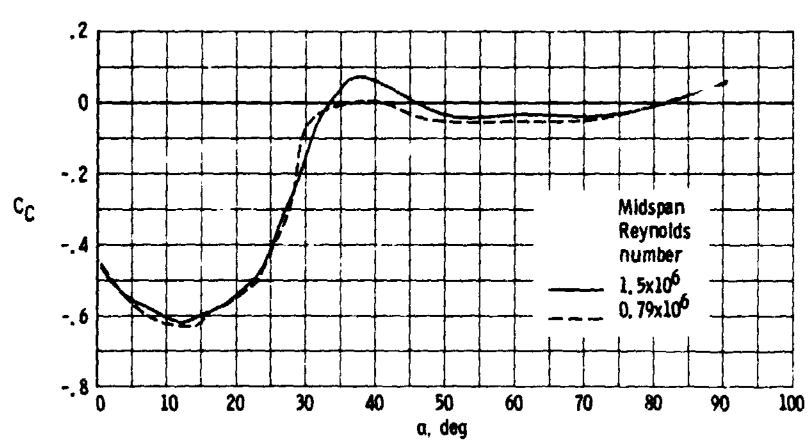

(a) Lift coefficient

Figure 12. - Effect of Reynolds number on the aerodynamic characteristics of the blade tip section with plain ailerons, trip strips on, all aileron gaps open, no vortex generators, aileron deflected 0°.



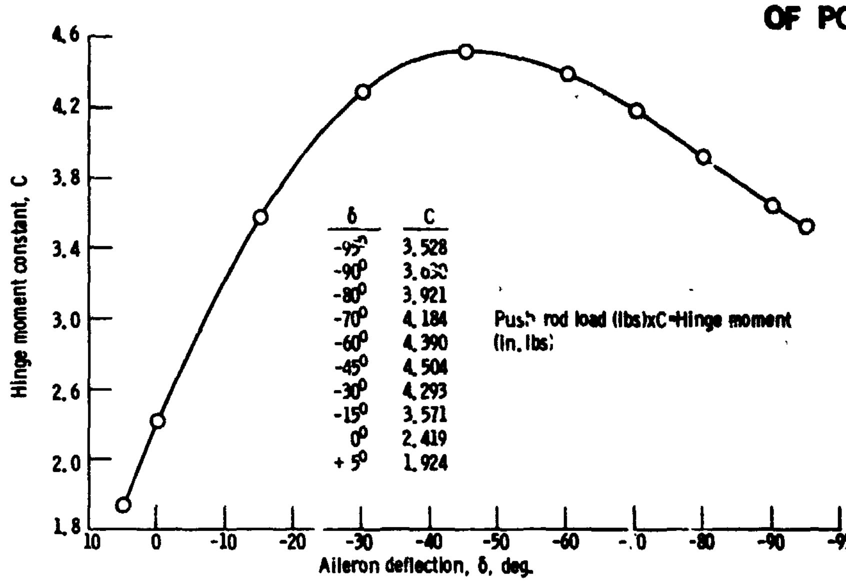

(b) Drag coefficient.

Figure 12.-Continued.




(c) Chordwise force coefficient.

Figure 12.- Concluded.




| δ | C |
|---|---|
| -95° | 3.528 |
| -90° | 3.[illegible] |
| -80° | 3.921 |
| -70° | 4.184 |
| -60° | 4.390 |
| -45° | 4.504 |
| -30° | 4.293 |
| -15° | 3.571 |
| 0° | 2.419 |
| +5° | 1.924 |

Figure A1.

## APPENDIX B
## TEST MATRICES

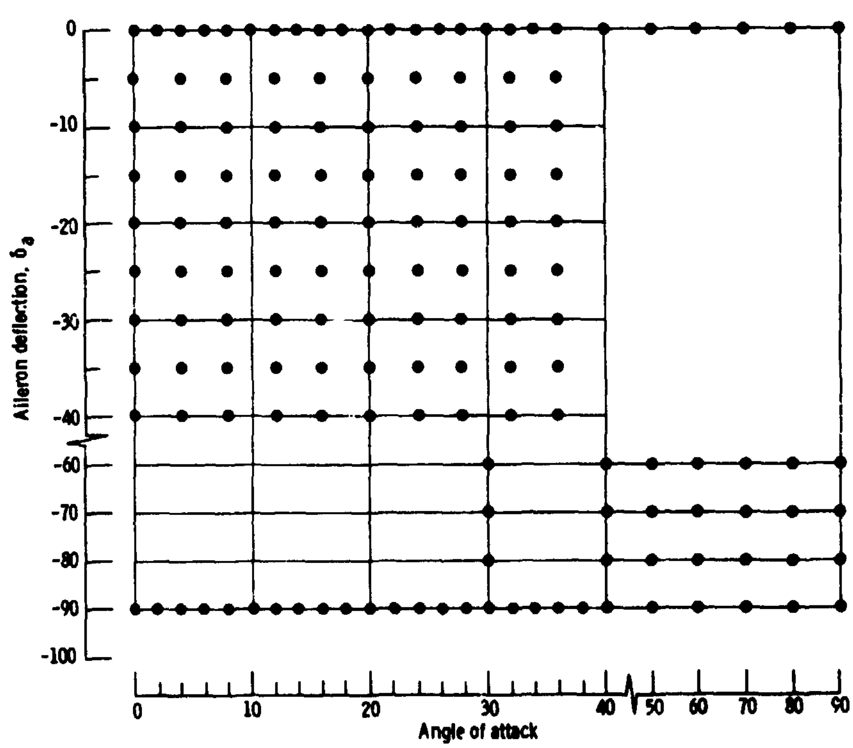



Figure B1. - Test Matrix for chordwise pressure measurements and angle of attack probe calibration
Leading edge condition: Trip strip with backward facing saw tooth.
Aileron type: Plain Tunnel wind speed = 61 mph.

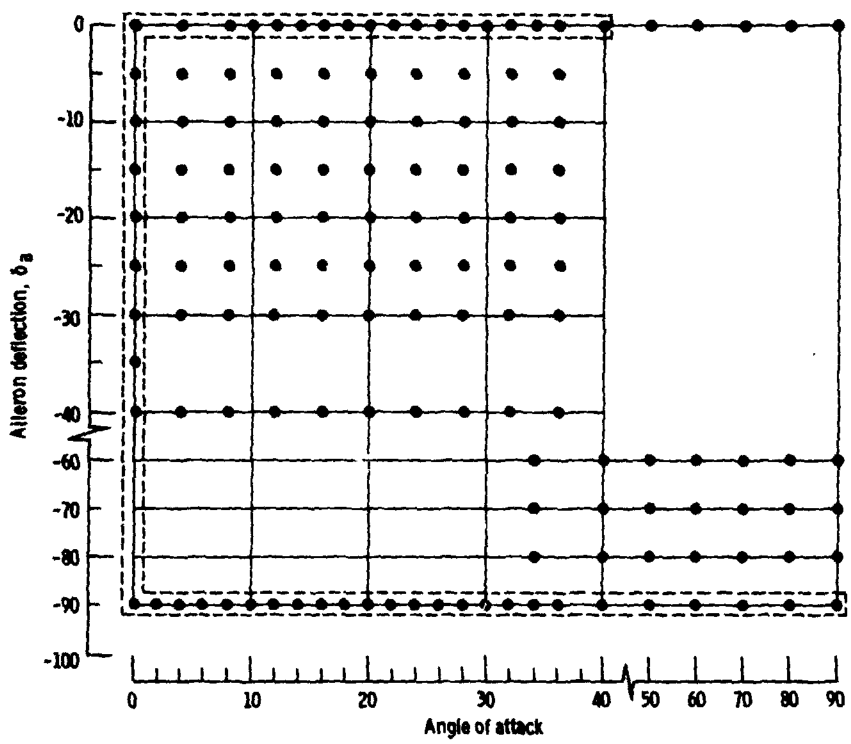



Figure B2. - Test Matrix
Aileron type: Plain, pressure cuff on, aileron gaps open
Leading edge condition: trip strip with sawtooth backward facing
Tunnel wind speed = 61 mph (all points)
33 mph (boxed points )

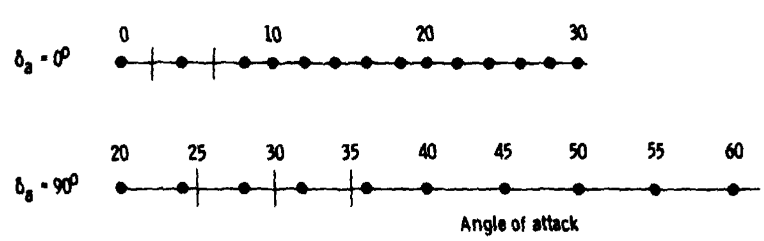



Figure B3. - Test Matrix for the following tip section condition

1. Leading edge tape on
2. Hinge line gaps sealed for $\delta_a$ = 0 and $-90^0$
3. Gaps at ends of aileron sealed only for $\delta_a$ = 0
4. Tunnel wind speed = 61 mph.

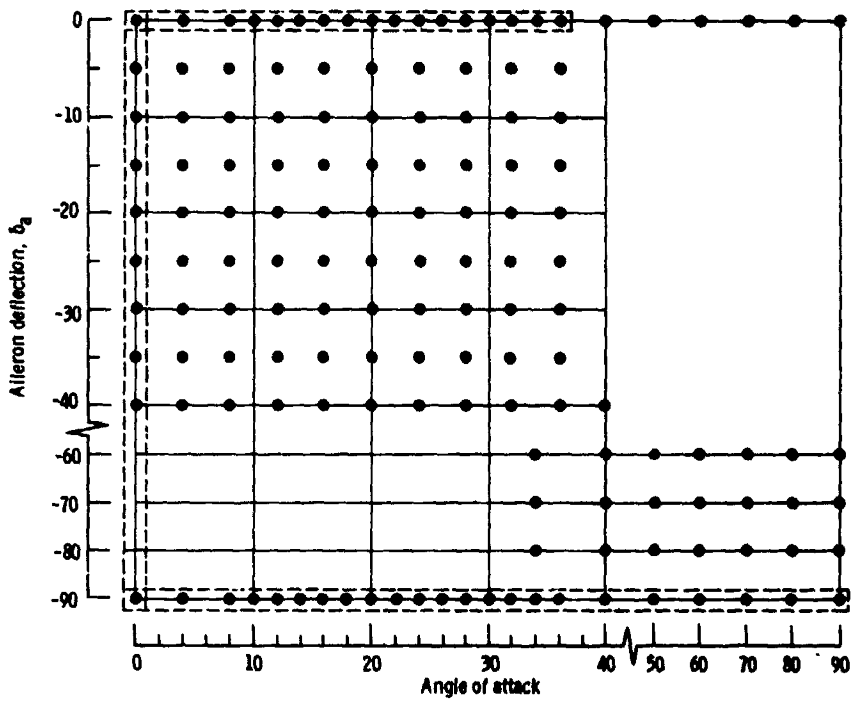



Figure B4. - Test Matrix
Aileron type: Balanced, pressure cuff off, aileron gaps open
Leading edge condition: Trip strips with backward facing sawtooth
Tunnel wind speed = 61 mph (all points)
33 mph (boxed points $\boxed{\bullet \;\bullet\; \bullet}$)

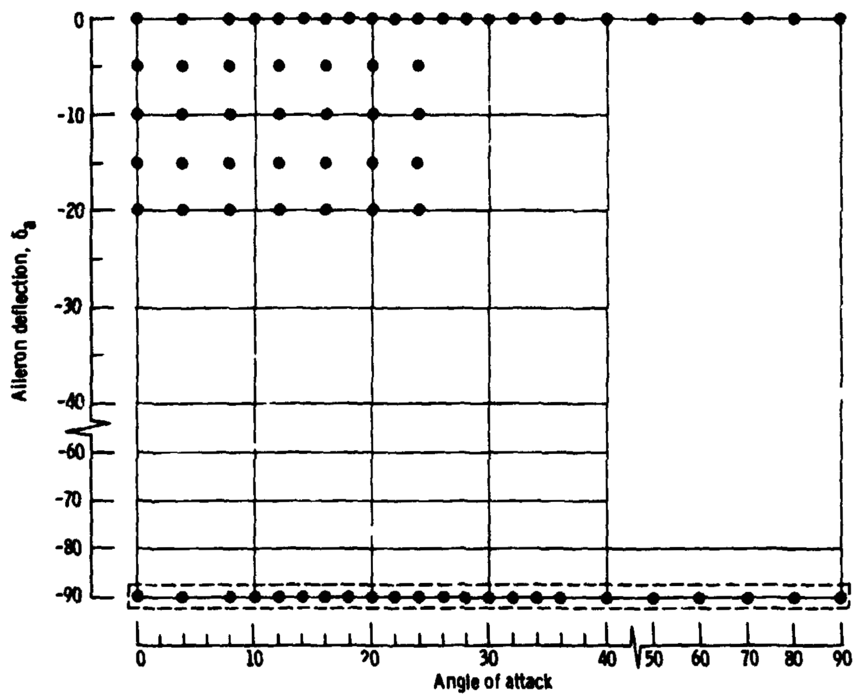



Figure B5. - Test Matrix
Aileron type: Balanced, no pressure cuff
Leading edge conditions: Vortex generators on suction side
Trip strips with backward facing sawtooth edge
Tunnel wind speed = 61 mph (all points)
33 mph (boxed points ● ● ● ●)

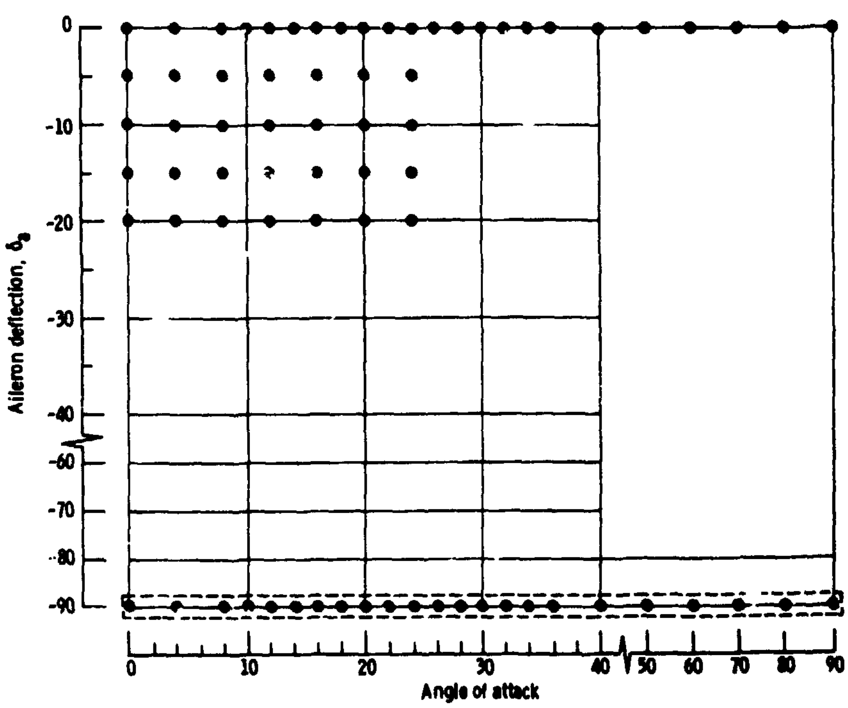



Figure B6. - Test Matrix
Aileron type: Balanced, no pressure cuff
Leading edge condition: Smooth (as received condition)
Tunnel wind speed = 61 mph (all points)
33 mph (boxed points)

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16. Abstract

Tests were conducted in the NASA Langley 30- by 60-Foot Wind Tunnel on a full scale 7.31 m (24 ft) long tip section of a wind turbine rotor blade. The blade tip section was built with ailerons on the trailing edge. The ailerons, which spanned a length of 6.1 m (20 ft), were designed so that two types could be evaluated: the plain and the balanced. The ailerons were hinged on the suction surface at the 0.62 X chord station behind the leading edge. The purpose of the tests was to measure the aerodynamic characteristics of the blade section for: an angle-of-attack range from 0° to 90°, aileron deflections from 0° to -90°, and Reynolds Numbers of 0.79 and $1.5 \times 10^6$. These data were then used to determine which aileron configuration had the most desirable rotor control and aerodynamic braking characteristics. Tests were also run to determine the effects of vortex generators, leading edge roughness, and the gaps between the aileron sections on the lift, drag, and chordwise force coefficients of the blade tip section.

17. Key Words (Suggested by Author(s))

Ailerons for Wind Rotors; Wind tunnel tests of wind rotor blade tips

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